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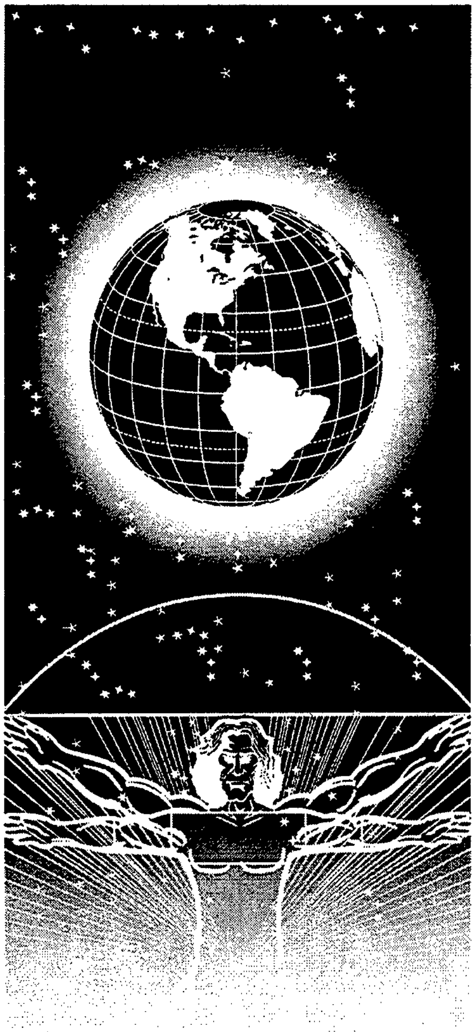

UNITED STATES AIR FORCE RESEARCH LABORATORY

LOW-LEVEL COGNITIVE MODELING OF AIRCREW FUNCTION USING THE SOAR ARTIFICIAL INTELLIGENCE ARCHITECTURE

David J. Darkow
William P. Marshak

SYTRONICS, INC.
4433 DAYTON-XENIA ROAD
BUILDING 1
DAYTON OH 45432

George S. Woodworth
Michael McNeese

HUMAN EFFECTIVENESS DIRECTORATE
CREW SYSTEM INTERFACE DIVISION
WRIGHT-PATTERSON AFB OH 45433-7022

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Wright-Patterson AFB OH 45433-7022

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FOR THE COMMANDER

Hendrick W Ruck

HENDRICK W. RUCK, PhD
Chief, Crew System Interface Division
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David J. Darkow, William P. Marshak, George S. Woodworth, Michael D. McNeese

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
SYTRONICS, Inc.
4433 Dayton-Xenia Road; Bldg 1
Dayton OH 45432-1949

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13. ABSTRACT *(Maximum 200 words)*

Pilot vehicle interface (PVI) testing usually requires extensive human-in-the-loop (HITL) simulation. An alternative to HITL testing is to model human computer interaction with an automated cognitive engineering tool.

This study used Soar cognitive modeling to compare the effectiveness of an existing and proposed PVI for air-to-ground Maverick missile missions. The baseline interface used a Forward-Looking Infrared Radar (FLIR) to detect and designate targets. The improved PVI had an enhanced FLIR and added Real-Time Information in the Cockpit (RTIC) with annotated overhead imagery of the target area.

The Soar software architecture was chosen to model pilot cognition, although target acquisition was more dependent on the pilot's visual and motor functions than cognition. The Soar model accurately predicated faster target acquisition for the RTIC PVI and faster target acquisition for reduced scene complexity. Although not statistically significant, the Soar model correctly indicated that increased scene complexity caused larger increases in target acquisition time for the RTIC PVI condition as compared to the baseline condition (HITL 179% increase, Soar 47% increase). Furthermore, Soar was the only model that accurately predicted increased latency in the RTIC condition while both Cognitive and Traditional Task Analyses predicted decreased latencies.

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ABSTRACT

Automated testing is an engineering tool used to test designs by exposing them to a variety of conditions and combination of conditions in an efficient manner. While guidelines exist for designing ***human computer interfaces (HCIs)*** or in the special case of aviation, the ***pilot vehicle interface (PVI),*** testing these interfaces usually requires extensive ***human-in-the-loop (HITL)*** testing. An alternative to HITL testing is to model human computer interaction in software and employ the model as an automated cognitive engineering tool for testing HCI/PVI design for the purpose of understanding the impacts on human performance and mission effectiveness.

The present study used computer simulation to compare the effectiveness of an existing and proposed PVI for air-to-ground strike missions employing the Maverick missile. The baseline interface involved using ***Forward-Looking Infrared Radar (FLIR)*** to detect and designate targets. The improved PVI enhanced FLIR contrast and added ***Real-Time Information in the Cockpit (RTIC)*** overhead imagery of the target area with targets marked. These PVIs had been previously tested by HITL simulations and several software models. Keeping this effort blind to the results of the previous efforts, the Air Force only provided task analyses and measures used in the earlier efforts so comparisons could be made.

The Soar software architecture was chosen to model pilot cognition because of its human-like cognitive capabilities. As it turned out, target acquisition for this particular mission scenario was more dependent on the parameters chosen for the pilot's visual and motor functions than cognitive processing. However, the Soar results presented here were comparable to HITL data and the other cognitive modeling simulations. Even though the visual and motor parameters chosen for the Soar model had limited correlation to the HITL data, the Soar model did accurately predict faster target acquisition for the RTIC PVI and faster target acquisition for sparser scene density. Although not statistically significant, the Soar model correctly indicated that increased scene complexity would have a greater increase on target acquisition for the RTIC PVI condition as compared to the baseline condition (HITL 179% increase, Soar 47% increase). However, the previous models failed to indicate the increased target acquisi-

tion times for increased scene complexity for the RTIC condition when compared to the baseline condition (***Cognitive Task Analysis (CTA)*** 105% decrease, ***Traditional Task Analysis (TTA)*** 124% decrease).

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Completion of this project would not have been possible without the cooperation of several individuals. Mr. David Hoagland, an engineer at the Air Force Research Laboratory, provided management assistance through the ***Crew-Centered Cockpit Design Technology (CCDT)*** Program Office. Mr. Tom Hughes of Veda Inc., provided data from the previously run simulations for comparison. Ms. Holly Bautsch of Logicon Technical Services provided valuable insights and a partial copy of her Masters thesis which was based on some of the previously run simulations. Dr. John Laird of the University of Michigan provided suggestions about Soar, its operations, and how it could be manipulated to create cognitive behaviors during an air-to-ground strike mission.

SYTRONICS' President, Barry Myers, encouraged this project as it was coincident with his company goal of creating leading-edge research. We would also like to thank all the other ***SYTRONICS*** employees who assisted in this work; Vince Schmidt and Brian Cooper for their technical assistance and Becky Rogers and Debbie Winner for assistance in preparing this document.

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INTRODUCTION

A growing number of accidents and incidents can be directly or indirectly attributed to mental errors made by human system operators (O'Hare, Wiggins, Batt, and Morrison, 1994). These errors are particularly disturbing to the engineers who build these systems because the hardware and software all worked as intended, but the result was still tragic failure. Clearly, there is a pressing need to be able to predict the circumstances leading to and ultimately diminishing the possibility of such mental errors. One approach to predicting such errors is to perform high-fidelity, HITL simulations and observe where cognitive breakdowns appear. Unfortunately, there are drawbacks to this approach which make thorough testing impractical. The combination of high-fidelity simulation costs, limits in skilled operator availability, behavior differences between simulation and real flying, and the limitless combinations of events capable of triggering cataclysmic accidents make thorough HITL testing impractical.

An alternative approach to HITL testing is to model the operator's cognitive performance, subject the model to the broadest range of possible circumstances, and record where the cognitive failures occur. This is analogous to automated testing which is already extensively used by engineers to increase product reliability. Although modeling human cognition is a fledgling science, modeling methods do exist, such as ACT* and Soar, which can serve as the basis for automated testing. Cognitive automated testing of user interfaces has both advantages and disadvantages. On the down side, automated cognitive testing lacks the face validity of HITL and the quality of the outcome is dependent on the quality and scope of the model. However, such testing can investigate large numbers of circumstances, especially unusual circumstances, at a lower cost and in less time. Furthermore, models can be readily changed and adapted as additional information and test runs become available. This kind of modeling could be used to predict which unusual circumstances cause these low frequency mental errors. Cognitive modeling could become a primary tool for designing and evaluating user interfaces, and potentially decrease the occurrence of metal errors.

Architecture Selection

Marshak, Pohlenz (now Wesler), and Smith (1996) considered how cognitive modeling could be employed in the crewstation design process and speculated on how best to implement such a model for Armstrong Laboratory's CCDT Program. A survey covered the existing cognitive modeling literature and identified the bases for a predictive aircrew cognitive model. The literature revealed two leading candidates in which to implement the cognitive model. The first is Anderson's ACT* (1983) architecture (current version ACT-R) which grew out of cognitive psychological theory; and Laird, Rosenblum, and Newell's (1985) State, Operator, and Result (Soar) architecture based on an artificial intelligence architecture which mimics human performance. The following explanation borrows heavily from Marshak, et al. (1996).

Anderson's (1983) ACT* model for cognition tries to provide a comprehensive explanation for high-level cognitive control behavior. There are three distinct memory structures in Anderson's model: working, declarative, and production. ***Working memory (WM)*** holds relevant information from declarative memory, sensory inputs, and the actions of productions (explained in the following). ***Declarative memory (DM)*** contains a tangled hierarchy of information clusters, each with no more than five elements. ***Production memory (PM)*** contains IF-THEN condition-action pairs with conditions drawn from DM and actions inserted in WM.

Anderson's theory is based on empirical findings of human learning and memory studies and as such, has been elaborated to match the theoretic thinking in that domain. This introduces elaborations as separating memories into temporal, spatial, and abstract classes. ACT* offers six kinds of interactions in WM and five different mechanisms for conflict resolution. Although these theoretic elaborations match the complexity of human cognitive processing theory, they also increase parameterization and allow multiple predictions based on which combinations of processes are operating.

A somewhat simpler human cognitive modeling scheme was proposed by Card, Morgan, and Newell (1983). The ***Model Human Processor (MHP)*** was a general model for human problem-solving. MHP postulated three interacting subsystems (perceptual, motor, and cognitive) each with their own processor and memories. Per-

ceptual stores include visual and auditory memories. Motor stores have the ability to store sequences of motor behaviors. Cognitive stores include working and long-term memory. Operation of the MHP model is based on the Recognize-Act cycle, where productions are drawn from long-term memory into WM and the results of their firing modifying WM. Operations are governed by the principles of discrimination (retrieval based on uniqueness), uncertainty (decision processes slow with uncertainty), and rationality (goal-orientation).

The MHP model has evolved into what is now called Soar. Soar is an advanced expert system software architecture which employs a decision engine modeled after human problem-solving. However, Newell (1990,1992) asserts that Soar is a candidate for a unified theory of human cognition instead of being just another computational expert system. Newell supports his claim based on a common mental chronometery (similarities in timing), a common architecture with perception and motor function, and a convergence of Soar's behavior with data on human operations and learning. Newell eloquently supports the relationship between Soar and human cognition by pointing out Soar can predict or explain many human learning and memory phenomenon.

Under Newell's urging, Soar incorporated human intelligence strategies as part of its software architecture. The first feature added was universal sub-goaling as a means of overcoming impasses. If Soar cannot initially achieve a solution to a problem, it defines more attainable sub-goals which are attainable. Once these sub-goals are attained, the final goal is tested again and if not yet achieved, new sub-goals are defined. This process continues until the ultimate goal can be attained from the last achieved sub-goal. Universal sub-goaling circumnavigates impasses without arbitrary assumptions or ineffective trial-and-error processes.

Another important feature of Soar is the use of chunking as a learning process during problem-solving. Chunking, the phenomenon reported by Miller (1959) that overcomes the limitations of short-term or WM, allows combination of IF-THEN production rules into related groups. The chunking hypothesis is that "A human acquires and organizes knowledge of the environment by forming and storing expressions, called chunks, which are structured collections of the chunks existing at the time of learning"

(pg. 142; Rosenbloom in Laird, Rosenbloom, and Newell, 1986). It uses a stimulus-response relationship between contents of chunks and follows from human learning theory. Chunking enables Soar to manage the complexity of large production rule bases by organizing them into chunks of increasing complexity. Rosenbloom goes on to show how Soar behavior seems to mimic human performance on memory and problem-solving tasks.

The Soar approach has certain advantages that favored its application in simulations over ACT-R. First, Soar is an extremely parsimonious approach to cognitive modeling; lower model complexity means a more deterministic approach. Perhaps even more important is that Soar is already being employed in modeling aircrew behaviors. The ***Defense Advanced Research Project Agency (DARPA)*** funded both Drs. Laird and Rosenbloom to develop ***intelligent forces (IFORs)*** for the ***Synthetic Theater of War (STOW)*** combat simulation. The Soar architecture had already been ported into the ***Modular Semi-Automated Forces (ModSAF)*** software system. ModSAF provides aircraft flight dynamics and weapons models while Soar provides the intelligence to "fly" IFOR aircraft autonomously. By using Soar, this substantial existing DARPA effort could be leveraged to create a working model with a minimum of time and effort. Another advantage to the Soar-ModSAF approach is that it is ***distributed interactive simulation (DIS)*** compatible. Models developed using Soar-ModSAF could be tested in complex DIS scenarios and improvements made by cognitive modeling could enhance Soar performance in STOW.

Background

The CCDT Program had already conducted a HITL simulation and created two different models to predict the effectiveness of cockpit display and control changes in the F-15 based fighter and its ability to deliver multiple Maverick missiles during a single attack run. The baseline configuration consisted of a F-16 cockpit simulation using the ***Low Altitude Night Targeting and Infrared Navigation (LANTIRN)*** targeting pod to deliver two fire-and-forget Maverick air-to-surface missiles. The LANTIRN pod provides a wide 6° and a narrow 1.69° field-of-view display through which the pilot must detect, identify, and designate the target vehicles. Targets were KC-10 tankers parked among

multiple (2 or 4) B-52 bombers on an airfield's ramps and taxiways. In a typical LANTIRN attack, the pilot will fly at medium altitude (7500 feet or 2286 meters) and airspeed (480 knots or 247 m/s) directly toward the target. The LANTIRN targeting pod FLIR display is used to view the target area and to designate targets for Maverick launch. When the target is within the Maverick's optimum range, the pilot fires one or more weapons at the designated targets.

The second configuration evaluated by the CCDT Program is an enhanced cockpit which was also HITL simulated and modeled. The enhanced cockpit contained two significant improvements. First, the RTIC provided a satellite view` of the attack area with all targets marked. Second, the FLIR was improved to provide 30% better contrast than the baseline FLIR image. It was anticipated that the advanced knowledge of the target location coupled with the improved LANTIRN FLIR contrast would reduce the target acquisition time and increase target designation accuracy.

The CCDT Program had already developed two other models of the baseline and enhanced configurations which were created to determine how well the models predicted the HITL simulation performance. One model was built using the ***Extended Air Defense Simulation (EADSIM)*** while the other was developed using MicroSaint™ modeling software. The CCDT Program wished to compare the Soar model with all three of the previous efforts. Thus, the present modeling effort was informed only of the dependent measures used in the other simulations and was otherwise kept "in the blind" to the results of the HITL, EADSIM, and MicroSaint™ simulations so that a fair comparison could be made. The performance of the other simulations was provided only after the Soar simulation was created and data collection runs were complete.

One problem identified early on about using Soar to model the CCDT Maverick launch mission is that this particular mission is very sequential in nature. Hence, the mission was not particularly mentally challenging and could not utilize the advanced cognitive modeling features of Soar, i.e., sub-goaling and chunking. The mission outcome is largely based on perception rather than cognition and calls for a modeling approach more suited to discrete event simulations rather than Soar's cognitive approach. Hence, the bulk of the results reflect the ability to predict the perceptual tasks. Under-

standing this lack of stress on Soar's capability, approval to build a Soar model of the Maverick launch mission was granted. The goal was to determine whether Soar could be used to micro-model pilot behaviors (STOW programming is at a tactical level), perceptual input, and motor output processes. This limited effort could be followed by a more comprehensive one which modified the mission with more cognitively-taxing characteristics which would completely test Soar's ability to cognitively model pilots with the hopes of developing a cognitive engineering tool for automatic testing of mentally-demanding, human computer interfaces.

SIMULATION DESIGN AND METHODS

Summary of Requirements

Mission

The ground attack mission begins with the pilot and vehicle at an altitude of 7500 feet, flying at a speed of 480 knots, and heading east toward the first waypoint, waypoint one. As indicated in Figure 1, the pilot then turns 90 degrees left and heads due North to the IP point and then continues due North to the target area where the pilot will designate, lock, and fire two Maverick missiles at two KC-10 aircraft on the ground (there are also four to eight B-52 aircraft on the ground and in the proximity of the KC-10s which serve as distracters). The starting point is at least 5.1km from waypoint one and waypoint one is 5.1km from the IP. All reported times are relative to the time the pilot reaches the IP point. All reported distances are relative to the target or target area.

The pilot knows there are four possible plane groupings for each trial, but only two of the four groupings will be populated in a given trial. The pilot knows that in each of the populated groups there will be only one target aircraft, a KC-10. Hence, once the pilot has identified and designated the KC-10 in the first group, the pilot can assume all the remaining, yet to be identified aircraft for that group are B-52s. Thus, the pilot will not identify the remaining aircraft in that group and the pilot can switch its attention to the second group. If the pilot miss identifies the KC-10 as a B-52 and identifies all the planes in a grouping as B-52s, then the pilot, knowing there must be one KC-10 in

the group, will “look” again at each plane until one plane is identified as a KC-10. After the pilot designates the second aircraft, the pilot switches to locking each of the Mavericks. The pilot then watches the range icon until the range is less than 58,000 feet. When the range is less than 58,000 feet, the pilot then pushes the fire button.

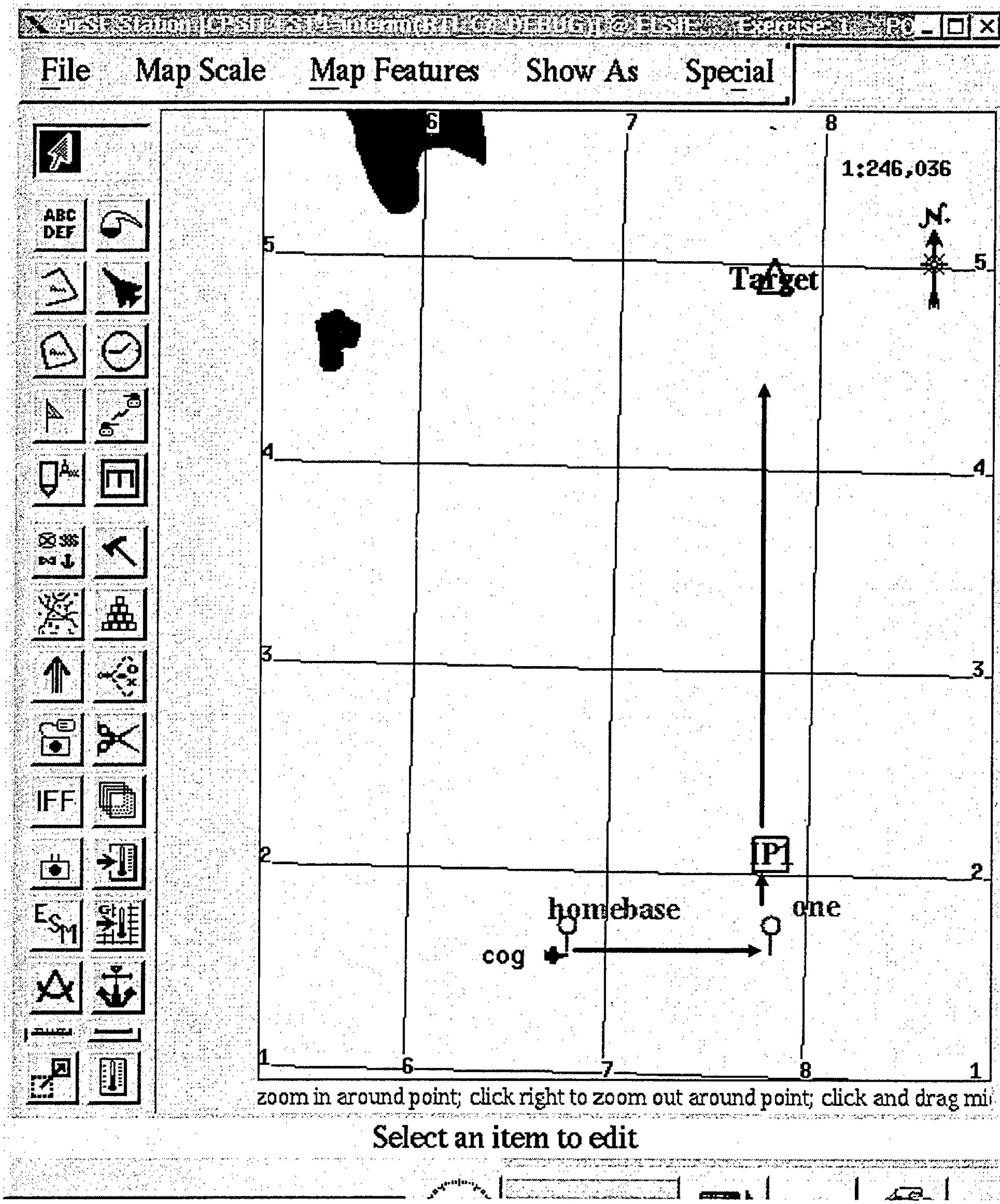


Figure 1. ModSAF Aerial View of Ground Attack Mission.

The behavior sequence is detailed graphically in Figures 2 and 3 and textually in the Appendix 1.3 and 1.4. Basically, there are two separate scenarios. The baseline scenario requires the pilot to detect a cluster of objects, then visually detect and identify each of these objects until a KC-10 is identified. After each instance that the pilot claims to detect a KC-10, the pilot designates that aircraft. After the pilot designates two aircraft, the pilot then switches to locking each of the Mavericks. Finally, the pilot watches the range icon and when the pilot is within 58,000 feet, the pilot pushes the fire button.

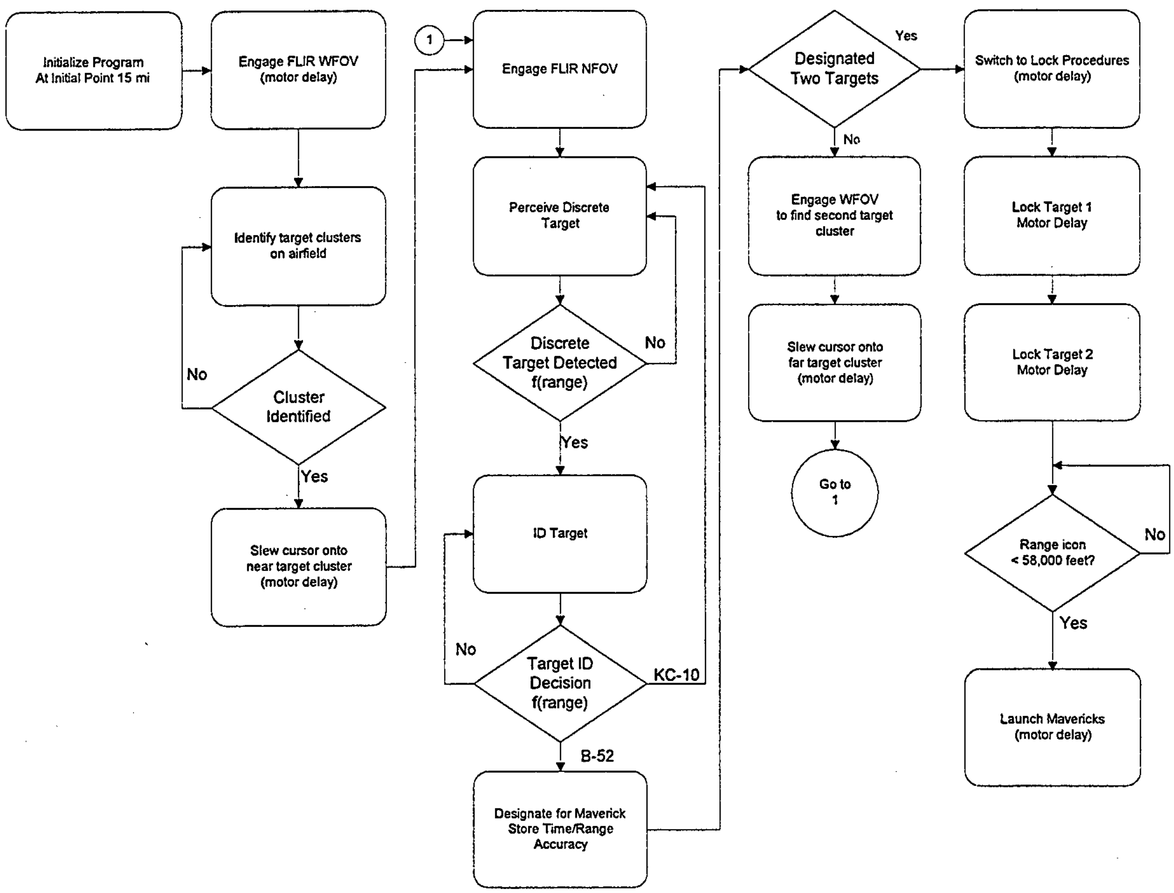


Figure 2. Flowchart of Baseline Behaviors.

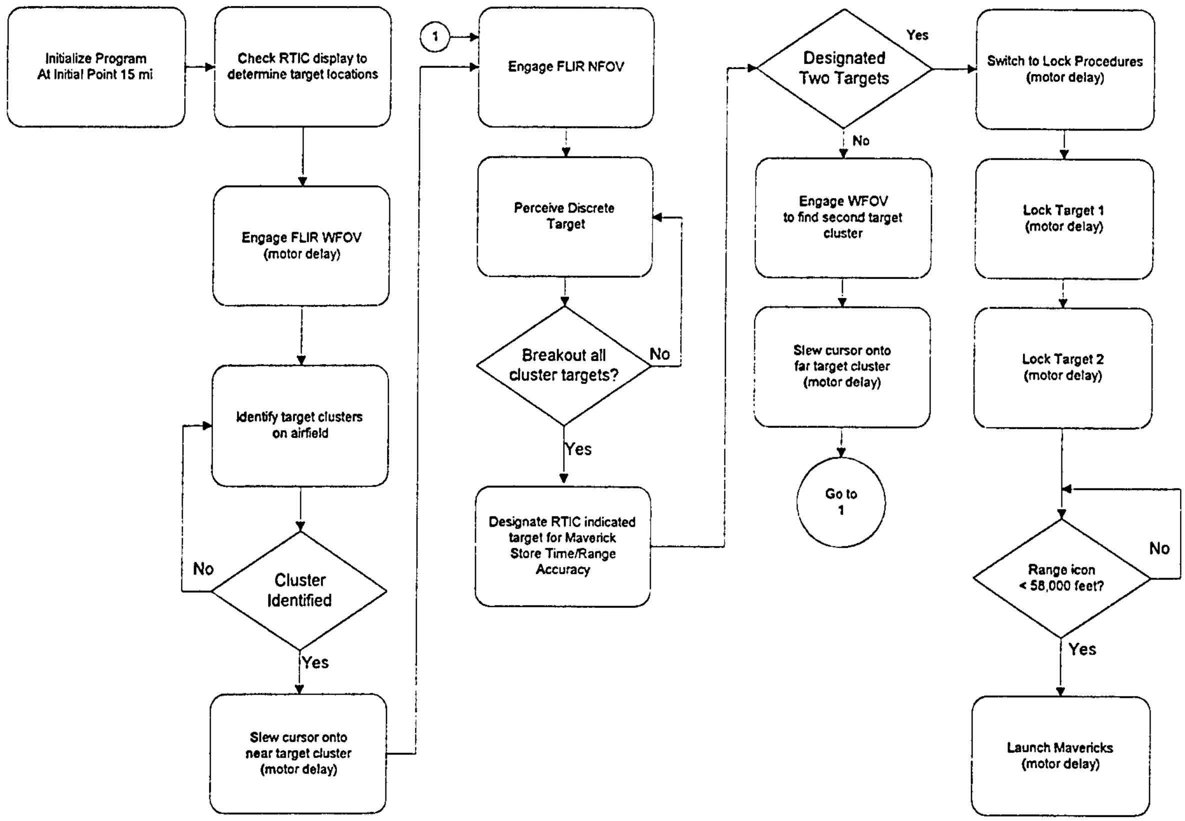


Figure 3. Flowchart of RTIC Behaviors.

In the second scenario, the RTIC condition, the pilot is given a satellite view of the aircraft on the ground and the target aircraft, i.e., the KC-10 is highlighted. The solution to representing this graphical intelligence information was to calculate the centroid for each group and then to calculate the polar position of each aircraft in the group relative to the centroid. The target was then the aircraft that matches the relative angle and distance to the group's centroid. Hence, after detecting all the planes in the first group, the pilot designates the plane that matches this intelligence information. After the pilot detects all of the planes in the second group, the pilot designates the plane that matches that intelligence information. After the pilot has designated two aircraft, the pilot then switches to locking each of the Mavericks. Finally, the pilot watches the range icon and when the pilot was within 58,000 feet, the pilot pushed the fire button.

After the pilot pushed the fire button, the program recorded the trial number, the number of hits, misses, false alarms, and correct rejections. The program also records the time elapsed since the IP point and the range to the target and range to the pseudo airfield for the following parameters:

- First detection
- First identification (0 for the RTIC scenario)
- First and second designation
- First and second Maverick lock
- Launch

Soar Behavior Design

Visual Model

The existing Soar visual model had a range of seven nautical miles with perfect visibility, i.e., at distance of 7.001 nautical miles, the Soar pilot had no information about an object. However, at 6.999 nautical miles, the Soar pilot knew all it could about the object: lateral range, slant range altitude, heading, speed, location, call-sign, and vehicle type. To simulate WFOV and NFOV characteristics, the existing Soar behaviors were enhanced. First, the Soar visual lateral-range was increased to 32,000 meters (104,918 feet). After an aircraft was detected, the object was then assigned a detection slant-range and an identification slant-range. The detection range assigned was designed to have an average value of about 28.6 km with a standard deviation of about 1.0 km. The distance of 28.6 km was chosen because at this range, both the KC-10 and B-52 would subtend about five pixels on a 300x300 pixel screen of a 6.0° WFOV sensor as indicated by Equation 1 and Figure 4.

$$\sin\theta = \text{opp/hyp or } \sin(0.05^{\circ})=25\text{m}/28.6\text{km} \quad \textbf{EQ .1}$$

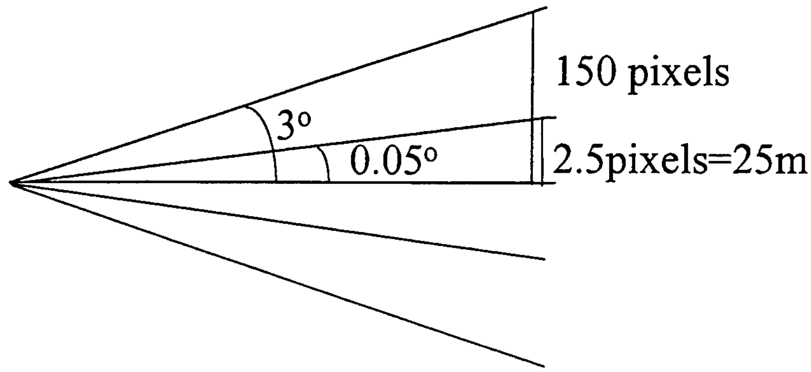


Figure 4. Diagram of WFOV Angels and Pixels Used to Calculate Slant-Range Detection Limit.

Determining the range at which a pilot could discriminate between a KC-10 and a B-52 required human subject data. Image pixelation was calculated based on aircraft size and range. The pixel subtense is plotted in Figure 5.

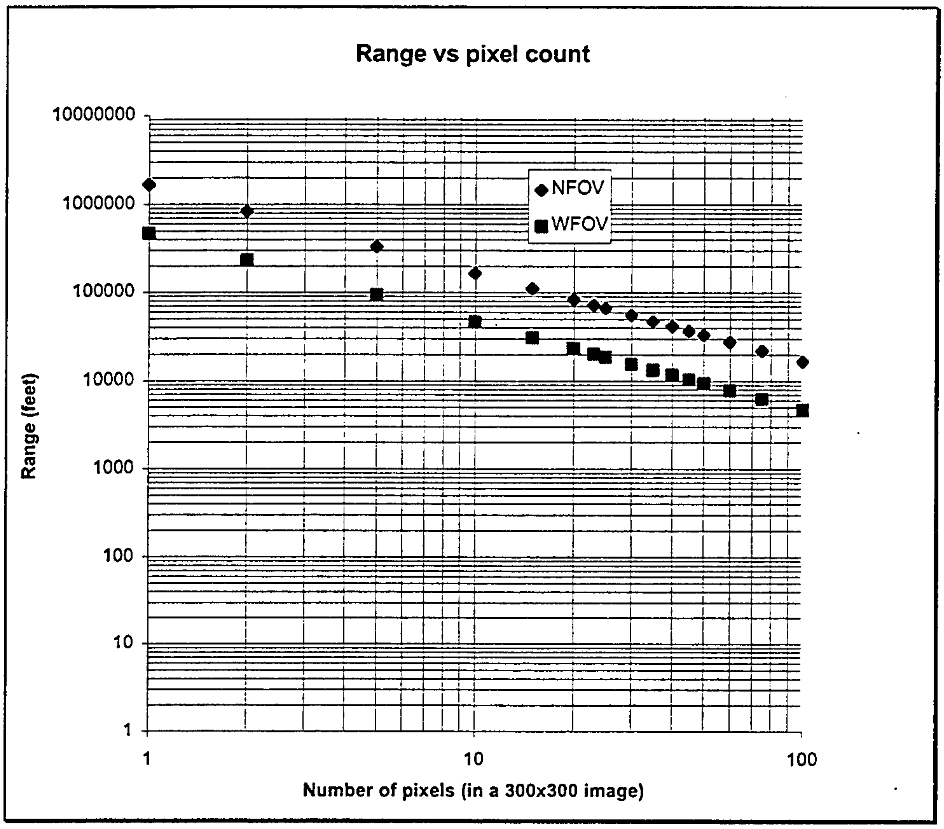


Figure 5. Estimation of an Aircraft's Length in Pixels vs Range for WFOV and NFOV FLIRs. The angles used were 6.0 and 1.69 degrees for WFOV and NFOV sensors respectively. The aircraft were estimated to have a 163 foot wingspan.

These calculations were the basis for creating pictures with the Image Processing Toolbox of Matlab (Thompson and Shure, 1995); an example of the output is shown in Figure 6. Human subjects were asked to identify pixelated reproductions of KC-10s and B-52s viewed from 15° angle above the horizon to approximate the medium altitude approach.

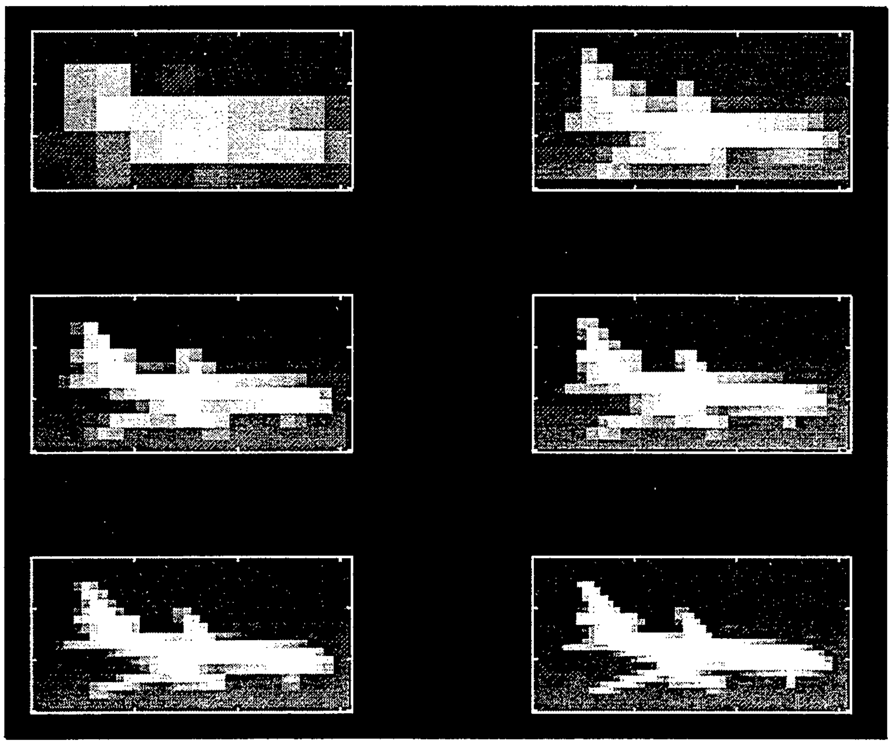


Figure 6. One Recognition Test Plate for KC-10 Viewed 60° Off-Axis from the Nose View.
See Appendix 1.2 for a complete set of B-52 and KC-10 pixelated images.

As seen in Figure 7, D' did not reach the 90% level until the plane subtended 25 pixels. The NFOV sensor has a 1.69° field-of-view. Thus, the minimum identification range can be calculated similarly to the WFOV calculations for detection range. The identification range is 20.3 km = 25m/sin(1.69° x25/300/2).

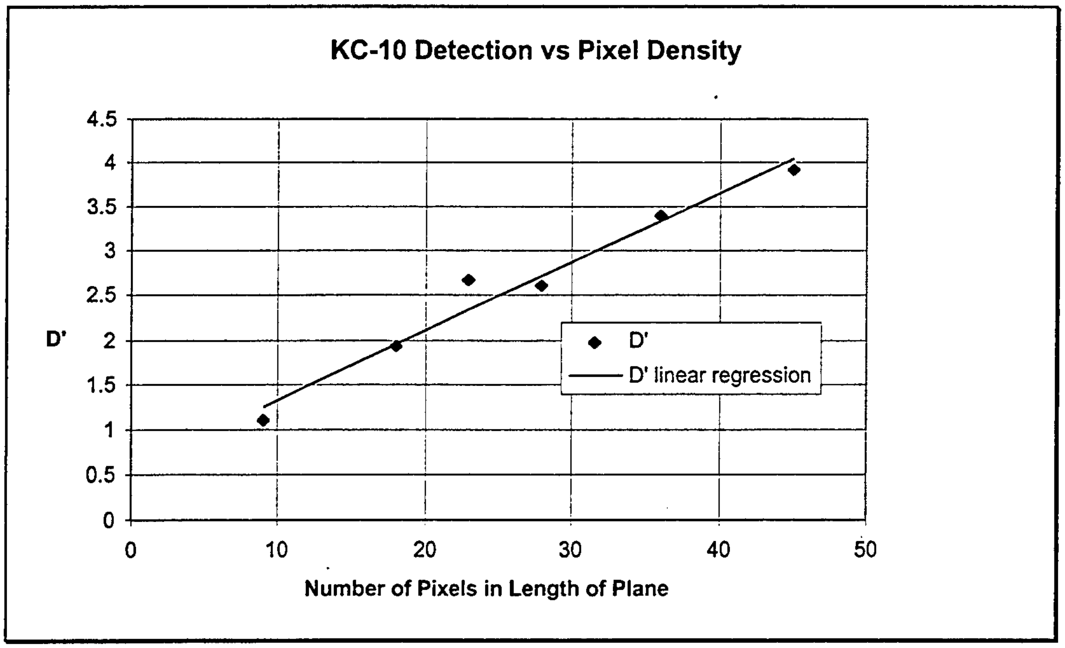


Figure 7. Ability of Novice Human Subjects to Discrimination Between KC-10s and B-52s Based Upon Pixel Density.

Thus, in the baseline scenario, the Soar pilot models discrimination between KC-10 and B-52 aircraft by the ability to see 25 pixels of the aircraft's length. However, an image subtending 25 pixels did not give the Soar model perfect vision. Behaviors were added so that at a displayed image of 25 pixels or slant range of 20 km, the pilot had a 90% chance of correctly discriminating between a KC-10 and a B-52. To model human behavior, the identification accuracy was dependent upon distance according to the following equations

$P_{identification} = 0$	Slant Range > 96,000 feet	**EQ . 2**
$P_{identification} = 2.93\text{-}3.045E\text{-}5*range$	96,000 < Slant Range > 63,000 feet	**EQ . 3**
$P_{identification} = 1$	Slant Range > 63,000 feet	**EQ . 4**

As seen in Figures 8 and 9, identification distance had an element of chance associated with both the RTIC and baseline behaviors.

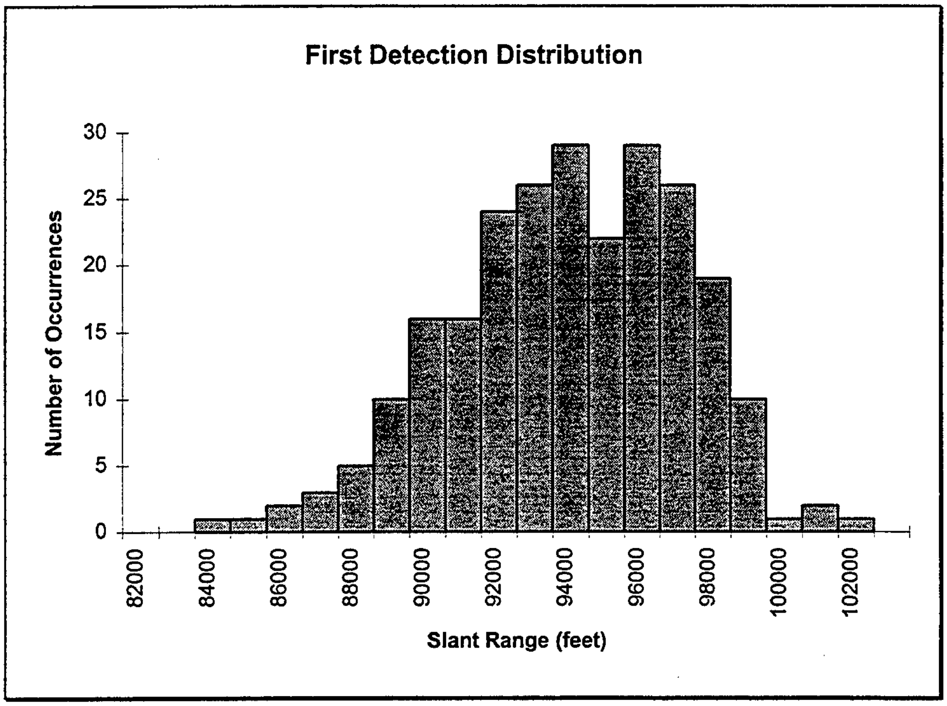


Figure 8. First Detection Distribution for RTIC Condition.

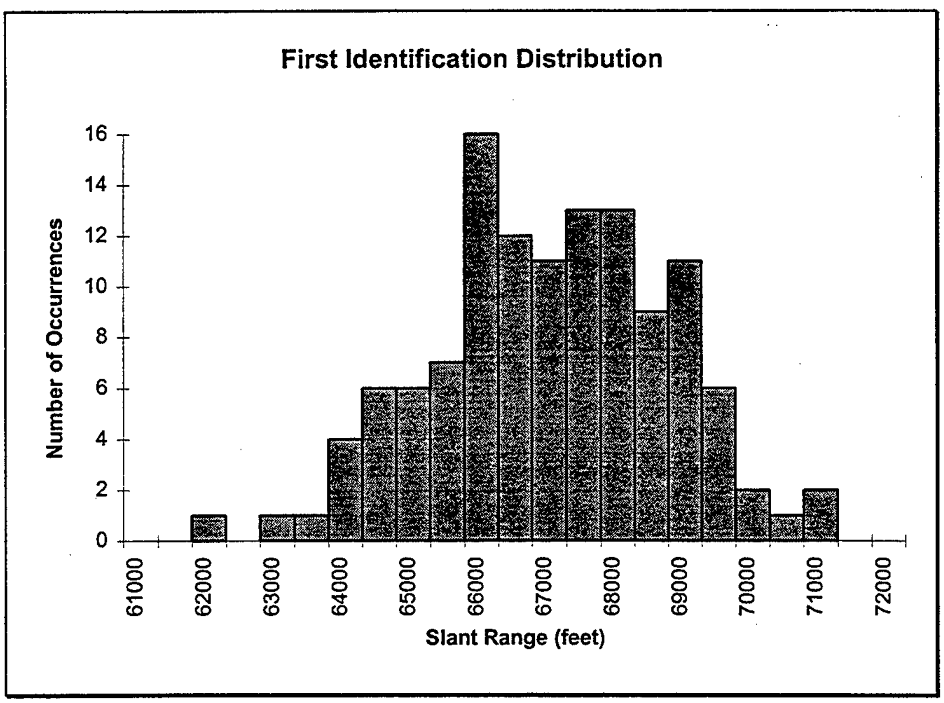


Figure 9. First Identification Distribution for the Baseline Condition.

In the RTIC scenario, the pilot did not need to visually discriminate between the KC-10 and the B-52. The pilot only needed to determine where the group of planes were, match the NFOV sensor image of the planes to the intelligence image, and then recognize the relative position of the target plane relative to the other planes in the group and then designate this same plane in the NFOV sensor image.

The solution to representing this graphical intelligence information was to calculate the centroid for each group of aircraft. Then, the polar position of each aircraft relative to the centroid was calculated. The target was then the aircraft that was both within 20 meters and 0.1 radians of the calculated distance between the centroid and KC-10 given in the intelligence information. Since the target position changed twice and the number of distracters changed twice, this caused the location of the centroid to be changed four times which required four sets of intelligence information. This mapping between the Soar supplied data located in files r1.soar, r2.soar, r3.soar and r4.soar and the plane layout configurations are seen in Table 1.

Table 1. The Associative Mapping Between Soar Supplied RTIC Information and Plane Layout Sourced at the ModSAF Parser

FILE NAME	PLANES PER GROUP	TARGET POSITION	PLANE LAYOUT (Corresponding file sourced at ModSAF parser)
r1.soar	3	1	1 - 6
r2.soar	3	2	7 - 12
r3.soar	5	1	13 - 18
r4.soar	5	2	19 - 24

Motor Model

Since the Soar language does not have any inherent mechanism for generating delays, the top-state attribute current-time was used as a timer. The resolution of the current-time attribute was one second. Hence, a delay set for one second has a theoretical delay of greater than zero but less than or equal to one second. Behavioral motor delays were added to prevent immediate execution of behaviors where motor delays were required. A summary of motor delays and the value of the programmed delays are seen in Table 2.

Table 2. Summary of Simulated Motor Activity and Corresponding Programmed Delay

MOTOR ACTIVITY	PROGRAMMED MOTOR DELAY
Engage WFOV	1
Switch to NFOV	1
Decide Hit, Miss, FA or CR	1
Designation and Confirm	1
Switch from Designation to Locking	3
Locking and Confirm	1
Launch	2

Randomization

Since Soar does not have a random number generator, random numbers were generated by calculating the sine value for the current-time value. To obtain a distribution that was not flat and had similarities to a gaussian distribution, three random numbers were averaged. To calculate the detection and identification ranges for each plane, the average of three random numbers were subtracted from 0.5 and this difference was multiplied by the variance for that parameter. This result was then added to the expected mean for that parameter. As seen in Figure 8 and 9, the distribution of detection and identification ranges have a gaussian-like distribution.

After the Soar pilot is focused on a particular plane and the slant range is less than the calculated identification range for that plane, then the probability for accurately identifying the focused vehicle is calculated as seen in equations 2, 3, and 4. This calculation is based upon the slant-range between the Soar pilot and the aircraft in question and a randomly-generated number having a flat distribution. If the calculated probability was greater than the randomly-generated number, then a hit or correct rejection was recorded. If the calculated probability was less than the randomly-generated number, then a miss or false alarm was recorded.

Program Description

As seen in Figures 2 and 3 (Flowcharts for Baseline and RTIC Behaviors) and Appendices 1.3 and 1.4 (selected text outputs from execution of baseline and RTIC behaviors), the mission starts with the Soar pilot flying toward waypoint one. After

achieving waypoint one, the Soar pilot turns north and flies to the IP. After achieving the IP waypoint, a timer is started, the pilot continues North at an altitude of 7,500 feet and speed of 480 knots and engages the WFOV. After a cluster of objects is detected, the Soar pilot switches to NFOV. The pilot continues to focus on one object in the cluster until it is both detected as a plane and identified. After identification, the validity of the identification is calculated and recorded as a hit, miss, false alarm, or correct rejection. Once a KC-10 is believed to be identified, a hit or false alarm, then the object is designated and the second cluster is processed. If a miss occurs, then all of the identification information for that group is erased after all the planes are identified and the identification process is repeated until a hit or false alarm occurs. After two aircraft are designated, the pilot switches to the launch procedures. The launch procedures consist of locking and confirming both of the Mavericks. After locking both Mavericks, if the slant range is greater than 58,000 feet, then the pilot watches the range icon. After locking both Mavericks, if the slant range is less than 58,000 feet, the pilot presses the fire button.

The RTIC behavior scenario differs from the baseline behavior outlined above in the identification process. In the RTIC behaviors the planes are not identified. After the cluster is detected in WFOV and the pilot switches to NFOV, the pilot focuses on each target and calculates the polar coordinates for that plane. If the plane's polar coordinates are not within the limits input by the intelligence information, then a correct rejection is recorded and the pilot proceeds to focus on the next plane in the group.

If the plane's polar coordinates are within the limits input by the intelligence information, then a hit is recorded, the plane is designated and the pilot proceeds to the next group or to launch procedures if this was the second group.

RESULTS

Analysis of Soar Model

The experiment contained two major variables, scene density and pilot vehicle interface. The scene was further complicated in that only two of the four possible vehicle locations were occupied. A bird's eye view of the field arrangement is presented in Figure 10. This requirement resulted in six different possible groupings (1-2, 1-3, 1-4,

2-3, 2-4, 3-4). Furthermore, the location of the target vehicle, the KC-10, was also varied between two locations within each group. Hence, the experimental matrix was a 2x2x6x2 which was repeated five times for a total of 240 trials. Table 3 summarizes these independent measures.

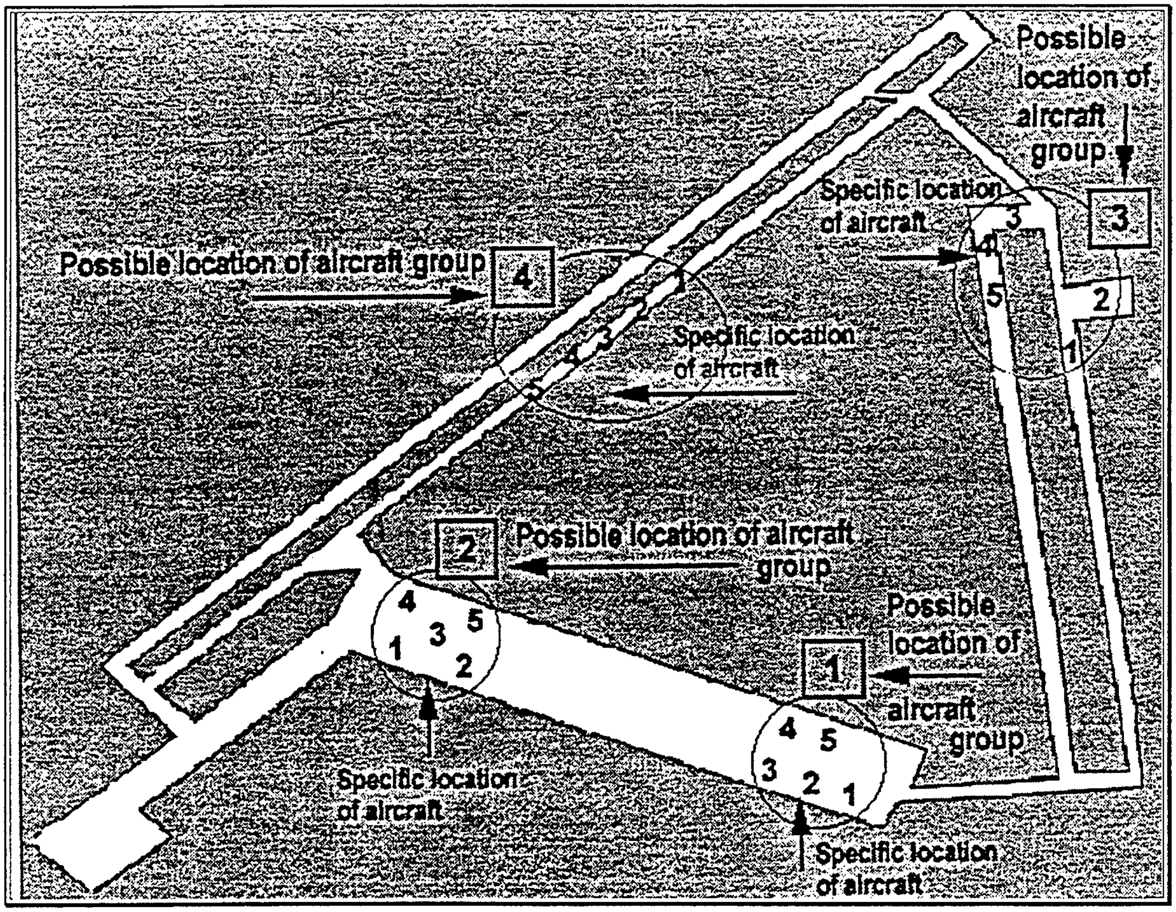


Figure 10. Airfield Area (from Holly Bautsch, 1997 pg. 27).

Table 3. Arrangement of Independent Measures Used in Prior Efforts and by the Soar Model

Variable	Levels	Variations
Pilot Vehicle Interface	2	Baseline Enhanced (RTIC)
Cluster Size	2	Three aircraft Five aircraft
Groupings	6	Two out of four possible airfield positions 1-2,1-3,1-4,2-3,2-4,3-4
Position in Cluster	2	Two positions used each in groups size three or five

The dependent variables measured included: detection time and range, identification time and range, designation time and range, lock time and range, launch time and range, and recognition accuracy. As seen in Figures 8 and 9, the modeling of detection and identification ranges did have a distribution that appears gaussian. The intended detection range average was 93,500 feet with a standard deviation of about 3,200 feet. The actual detection slant-range for all trials was 93,989 with a standard deviation of 3,247 feet. Similarly, the intended identification range average was 66,500 feet with a standard deviation of about 1,600 feet. The actual identification slant-range for all trials was 67,030 with a standard deviation of 1,729 feet.

As expected from analysis of the visual model, the Soar-simulated RTIC interface resulted in significantly earlier designation and lock times compared to the baseline condition (first designation time: $p=0.001$, $F=3352$, $N=60$; first lock time: $p=0.0001$, $F=3872$, $N=60$). As seen in Figure 15, the first lock time for the RTIC condition with a scene complexity of three averaged only 21.25 seconds. The RTIC condition with a scene complexity of five was 2.2 seconds higher, due to the increased scene complexity. Conversely, the baseline condition with a scene complexity of three had an averaged first lock time of 54.72 seconds, 33. 47 seconds longer than the RTIC condition. Similarly, scene complexity increased baseline first lock time by 1.58 seconds. Although the PVI and scene complexity interaction was not statistically significant, the increased effect for the RTIC condition should have resulted because in the RTIC condi-

tion, the Soar pilot must process each of the planes prior to identifying the target. However, in the baseline condition, the Soar pilot can terminate processing a group after the KC-10 is identified. Thus, in the baseline condition, the average number of vehicles expected to be processed with a scene complexity of three is two and with a scene complexity of five is three. Hence, increasing the scene complexity in the baseline condition will not increase the average lock time as much as the RTIC condition, but the variation should be much larger in the baseline condition. The variation in RTIC first lock times are about 4.5 seconds regardless of scene complexity. However, baseline lock time variation is 3.37 seconds for a scene complexity of three and increases to 4.04 seconds for a scene complexity of five. Although this time difference in variance is not significant ($F=1.44$, $N=60$), the difference in variance for first lock range for baseline condition between scene complexities is significant ($F=1.88$, $N=60$). The explanation for the significance is that the time has an increased variance due to the different times it takes to reach the same slant range from each group since the target groups are located at different distances from the IP.

Overall accuracy of performance was comparable for the four experimental conditions. Categories of responses for each condition are plotted in Figure 11. The most marked difference is the increased number of correct rejections when more B-52s appeared in target clusters.

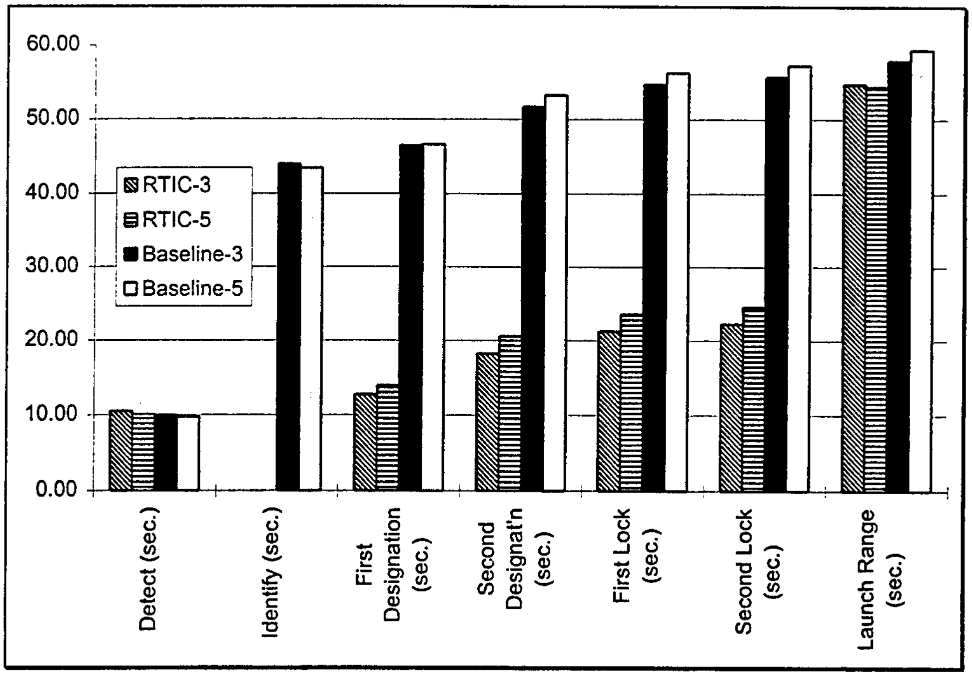


Figure 11. Summary of Soar Simulation Times for Different Scene Complexities and Different PVIs.

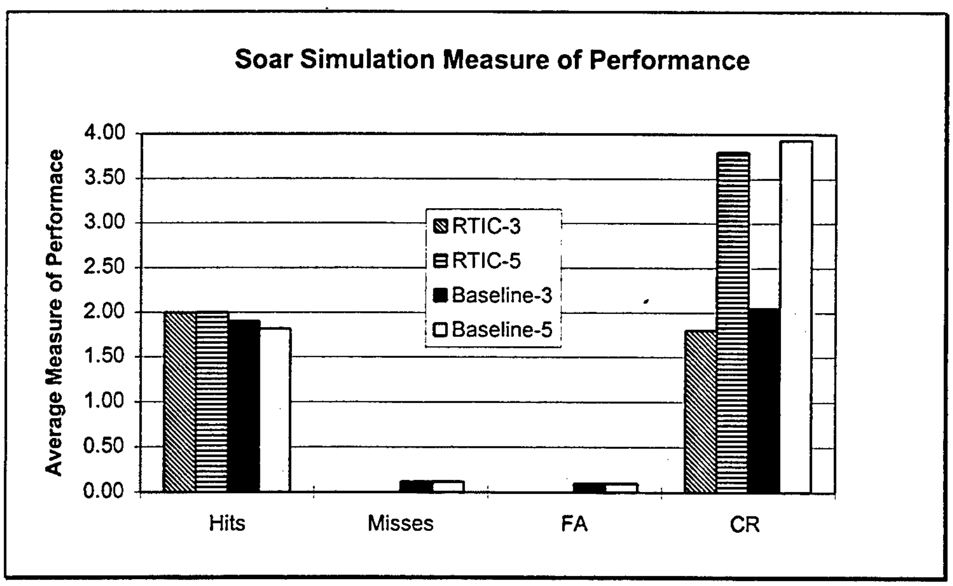


Figure 12. Summary of Soar Simulation Performance Measurements for Different Scene Complexities and Different PVIs.

The launch times between all conditions were very similar. The baseline behaviors typically resulted in the identification of targets and the locking of the Maverick missiles inside the maximum launch range. Hence, the baseline Soar pilot was typically

not waiting for the range icon to reach 58,000 feet. This resulted in a launch variation that was less than first lock variation due to clipping at the maximum launch range tail of the distribution as seen in Figure 12. Conversely, the variation in RTIC launch ranges was very small as seen in Figure 13 with range scales comparable to the baseline condition. This greatly reduced variation because in all the RTIC conditions, the Soar pilot was always watching the range icon waiting to pass the maximum firing range of 58,000 feet.

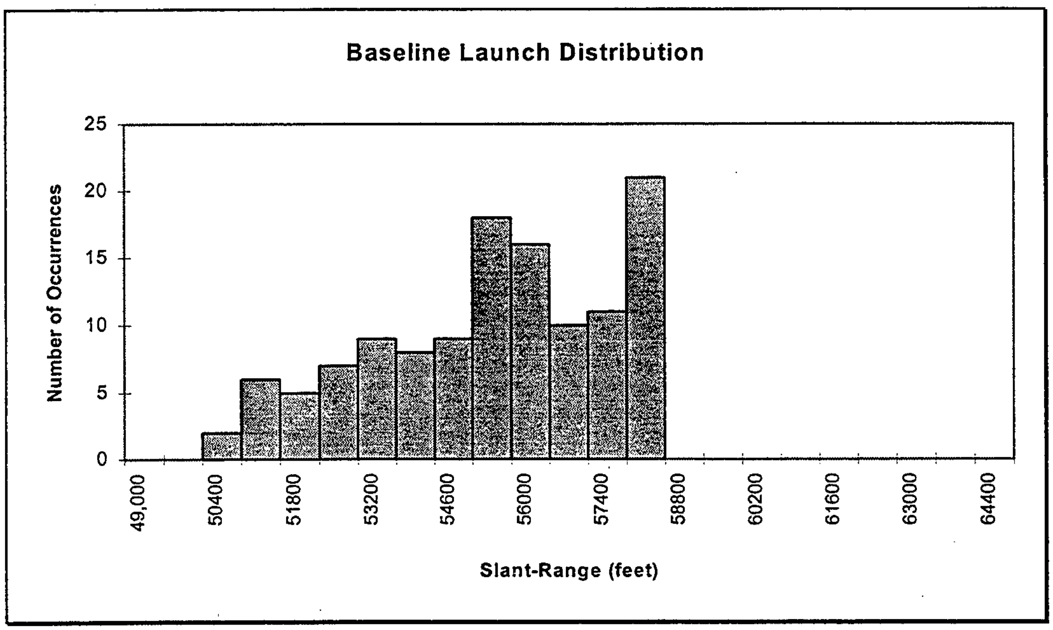


Figure 13. Distribution of Launch Ranges for Soar Model of Baseline Configuration.

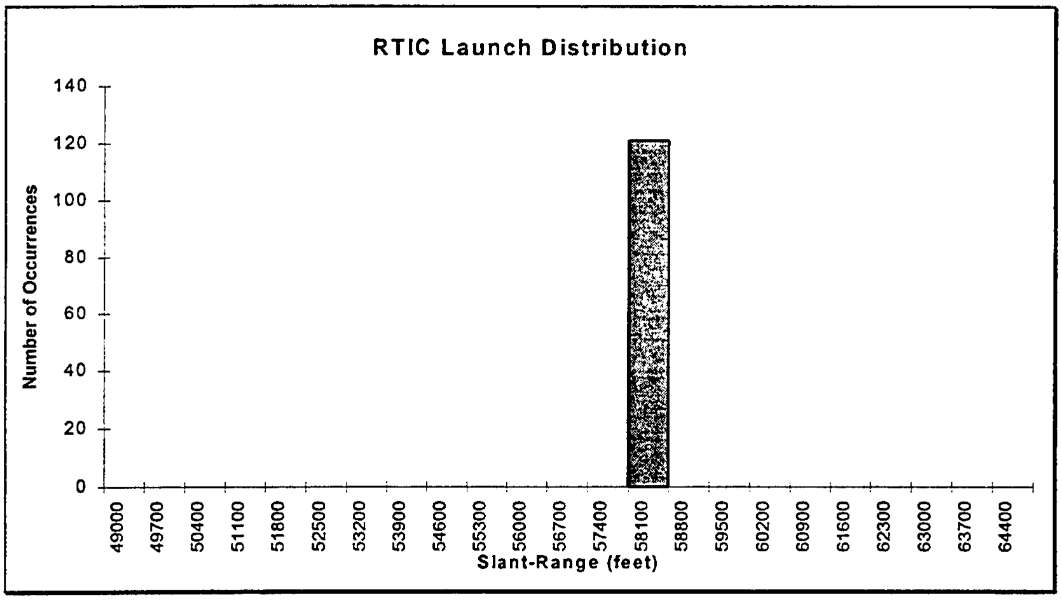


Figure14. Distribution of Launch Ranges for Soar Model of RTIC Configuration.

Comparison of Soar Simulation Results to HITL, TTA, and CTA Simulations

After completion of the Soar simulation data collection process, data from HITL testing and other simulation models were compared to the Soar-simulated results. The results from HITL, Soar, ***Traditional Task Analytic (TTA),*** and ***Cognitive Task Analytic (CTA)*** are summarized in Table 4. As seen in Figure 15, the Soar, TTA, and CTA simulations grossly under-estimated the first lock time for the baseline conditions, but Soar did surpass the TTA and CTA models in predicting RTIC first lock times. The Soar simulation over-estimated the first lock time in the sparser scene complexity indicating an under-estimation of the detection range in the visual model for the RTIC condition. In fact, close examination of the HITL data indicated that some pilots were locking targets prior to the IP point. Furthermore, Soar was similar to the other models in accurately indicating that additional distracters would increase the time required for a pilot to lock the missiles; although all simulations under-estimated the HITL data.

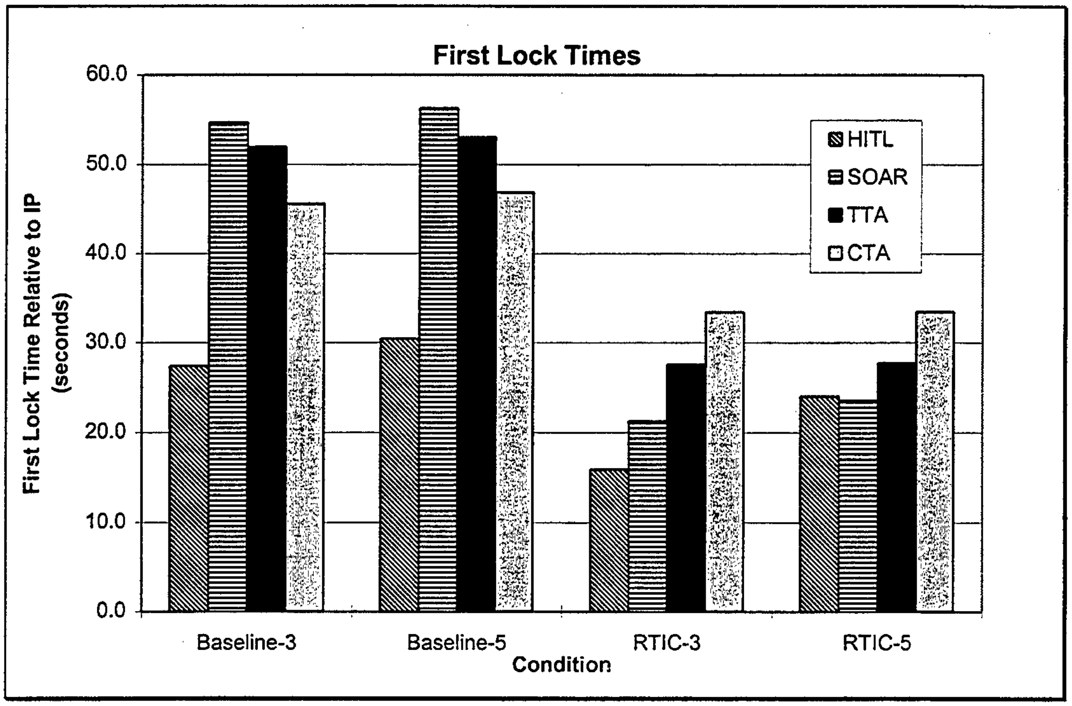


Figure 15. Comparison of HITL First Lock Times to Soar, TTA, and CTA Base Simulations.

Table 4. Data Summary of Soar HITL, TTA, and CTA Data

	SOAR				PIL (-32.98 seconds)				TTA (-32.98 seconds)				CTA (-32.98 seconds)			
Pilot Vehicle Interface	RTIC		Baseline		RTIC		Baseline		RTIC		Baseline		RTIC		Baseline	
Scene Complexity	3	5	3	5	3	5	3	5	3	5	3	5	3	5	3	5
Dependent Measure	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)	(sec.)
Detect (sec.)	10.53	10.10	9.97	9.78												
Identify (sec.)	0	0	44	43												
First Designation (sec.)	12.75	13.90	46.47	46.63												
Second Designation (sec.)	18.25	20.55	51.72	53.30												
First Lock (sec.)	21.25	23.55	54.72	56.30	15.95	24.02	27.40	30.42	27.55	27.72	51.99	53.07	33.47	33.48	45.59	46.87
Second Lock (sec.)	22.25	24.55	55.73	57.30	26.92	39.93	44.70	49.37	35.19	35.17	61.94	62.36	40.81	40.71	55.57	55.99
Launch Range (sec.)	54.78	54.43	57.93	59.42	40.77	53.28	58.28	62.27	40.23	40.02	67.19	67.27	40.23	40.02	67.19	67.27
Launch Range (feet)	57894	57909	56147	54378	56845	46937	44552	42464	2912	29131	6201	6132	26861	27181	14581	14363
Hits (average)	2.00	2.00	1.90	1.82												
Misses (average)	0	0	0	0	0	0	0	0	6	10	4	3	14	6	0	0
FA (average)	0	0	0	0	3	8	3	13	0	0	8	28	0	0	0	0
CR (average)	1.80	3.80	2.05	3.93												

NOTE: All times are expressed relative to IP. HITL, TTA, and CTA times were adjusted by using the average HITL time and range values from Holly Bautsch's thesis Tables 11 and 14 (32.98 seconds were subtracted from time values in order to make times relative to the IP).

Soar estimated the second lock time much better than the first as indicated in Figure 16. However, this improved estimate was due to the cancellation of a sluggish visual model and a hyperactive motor activity model. Given those limitations, one would expect that those differences would be canceled out when comparing PVIs of the same scene density. The HITL data indicated that for a scene complexity of three, the RTIC condition reduced the average second lock time by 17.78 seconds as compared to Soar, TTA, and CTA which reduced the averaged second lock time by 33.48, 26.75, and 14.76 respectively. This data is summarized in Table 5.

Careful analysis of the available HITL data shows an apparent confound. The presentation order to the human pilots appears not to be counter-balanced for presentation order with respect to scene complexity. Apparently, for a given PVI, a scene complexity of five was always given first and a scene complexity of three seconds. The HITL data for each subject was taken in four sets of four trials where the baseline and RTIC conditions were interwoven. The difference between sets for a given PVI is seen in Figure 17 as a step function between the fourth and fifth trials which corresponds to the end of the first set and beginning of the second set. Whether this difference is due to a learning effect in the RTIC condition or a training effect is confounded.

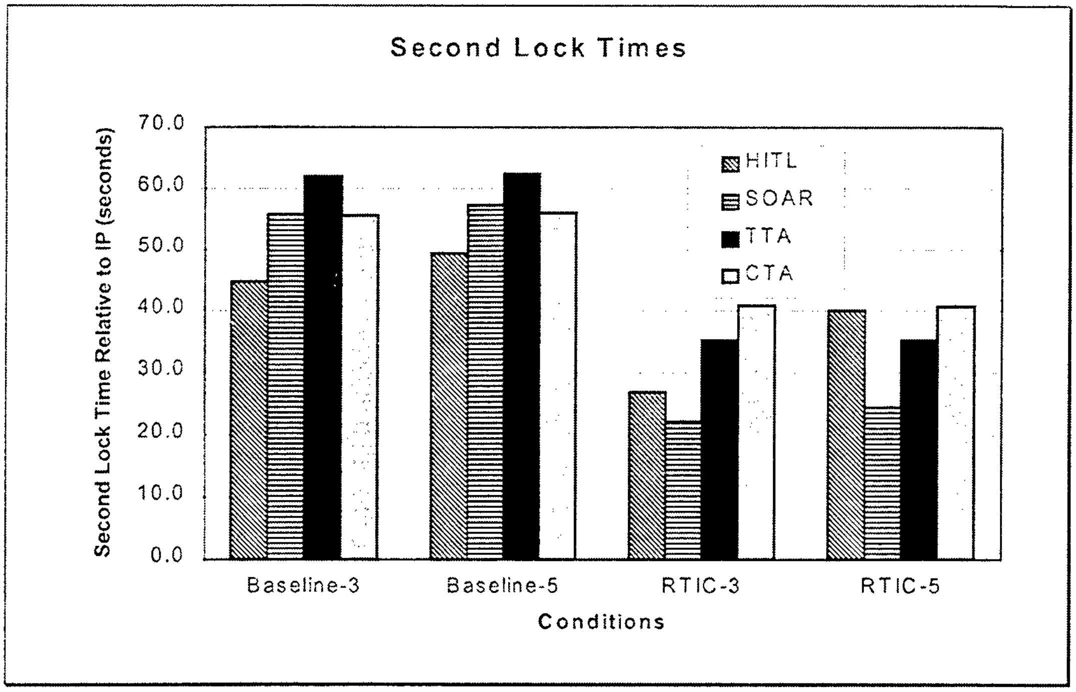


Figure 16. Comparison of HITL Second Lock Times to Soar, TTA, and CTA Base Simulations.

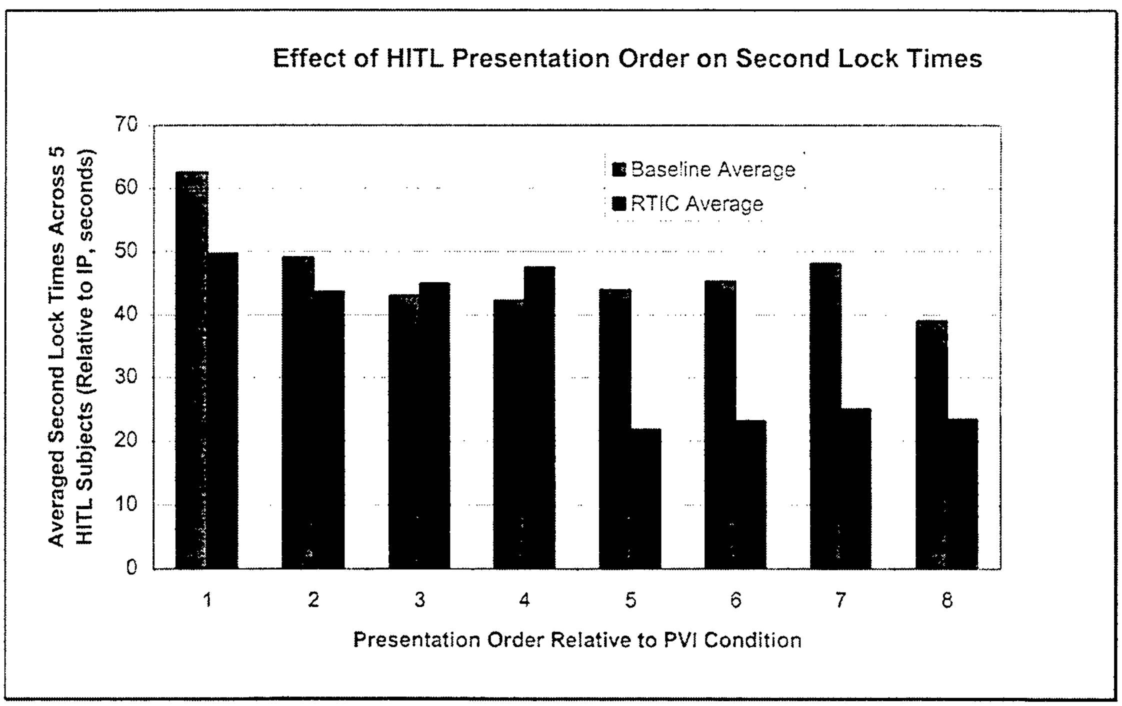


Figure 17. The Effect of Presentation Order on HITL RTIC Performance.

Table 5. Differential Comparison of Second Lock Times.
The scene density was three for both PVI conditions (all times are relative to the IP).

	Baseline-3 (sec.)	RTIC-3 (sec.)	Difference (sec.)	Error (%)
HITL	44.7	26.92	17.78	
SOAR	55.73	22.25	33.48	88
TTA	61.94	35.19	26.75	50
CTA	55.57	40.81	14.76	-17

The second lock times also reveal a cognitive effect in the comparison of increased scene complexity. In the baseline condition with three vehicles, on average, the pilot will have to identify two aircraft before finding the KC-10. In the baseline condition with five aircraft, on average the pilot will have to identify three aircraft before finding the KC-10. Thus, in the baseline condition, typically the pilot only needs to focus upon one additional vehicle, whereas the RTIC condition requires focusing on two additional aircraft when the scene complexity is increased from three to five. Hence, scene complexity is expected to increase second lock times for the RTIC condition in comparison to the baseline condition. As seen in Table 6, both HITL data and Soar simulation data have increased scene complexity differences for the RTIC condition as compared to baseline. However, the TTA and CTA models poorly simulate the RTIC scene complexity differences.

Table 6. Scene Complexity Average Differences for Second Lock Times.

Model	Baseline (sec.)	RTIC (sec.)	Change (%)
HITL	4.67	13.01	179
SOAR	1.57	2.3	47
TTA	0.42	-0.02	-105
CTA	0.42	-0.10	-124

Analysis of launch time differences between conditions is difficult. In the baseline conditions, the HITL and Soar data are very similar. This increased similarity over second lock time is attributed to an apparently hyper motor model of the Soar simulation. What is lost in the Soar simulation is a difference between PVI conditions. This is because the Soar model used a maximum launch range of 58,000 feet. Since the baseline behaviors were near completion at this point and RTIC behaviors always waited to pass this threshold, the benefits of the RTIC behaviors are not identifiable for this measurement. Conversely, HITL data show decreased RTIC launch times because that data did not appear to have a maximum Maverick launch range (one pilot launched from 76,650 feet).

Analysis of launch range is similar to launch time except the TTA and CTA data are problematic. As seen in Figures 18 and 19, it is unknown how launch times for HITL, TTA, and CTA can be so similar, but launch ranges can be drastically different.

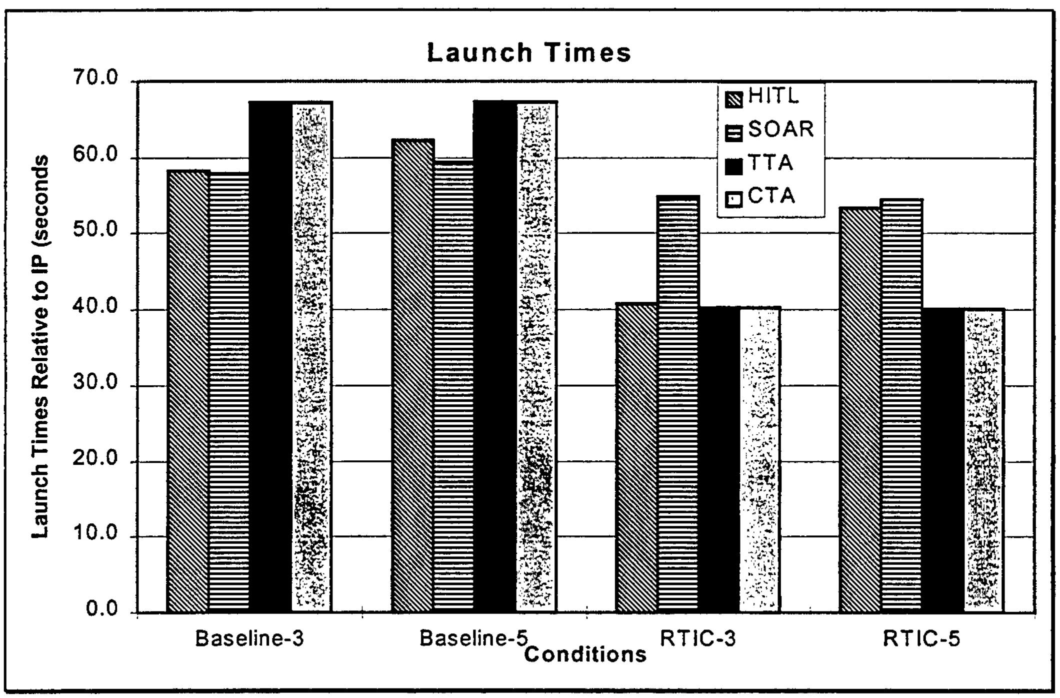


Figure 18. Comparison of HITL Launch Times to Soar, TTA, and CTA Based Simulations.

NOTE: The better results are the launch times with the lower values because these launches occur closer to the IP point and, therefore, further from the target area.

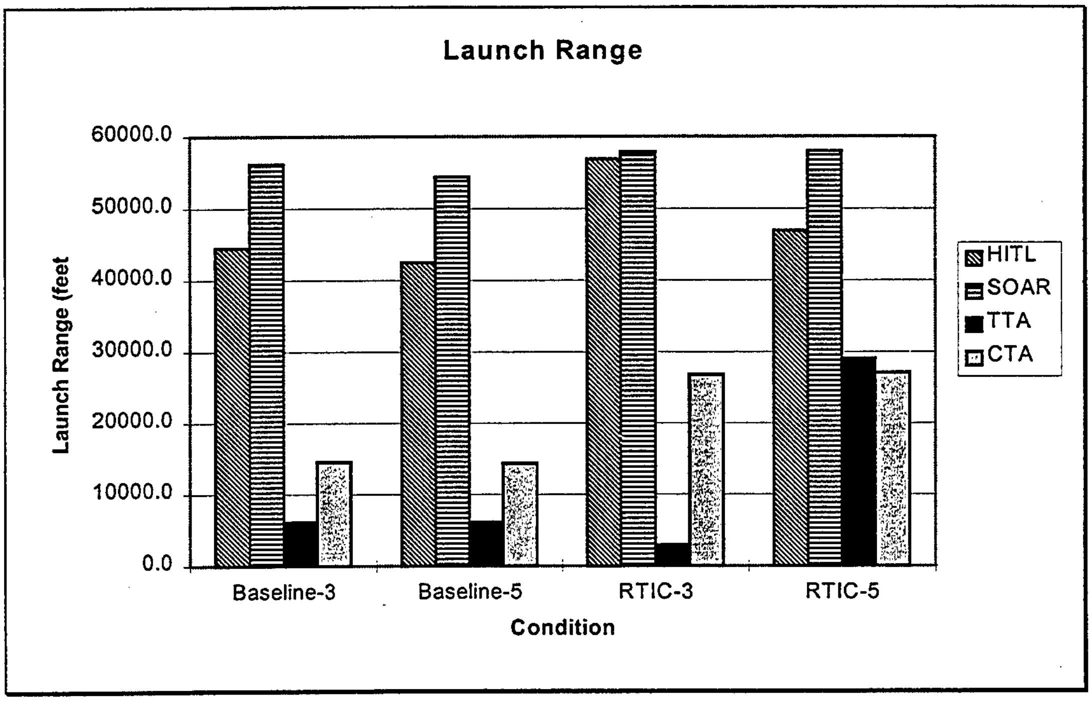


Figure 19. Comparison of HITL Launch Ranges to Soar, TTA, and CTA Based Simulations.

Table 7 shows the number of false alarms increased in the baseline condition as scene complexity increased for HITL, Soar, and TTA simulations. However, the number of misses decreased as scene complexity increased. The explanation is that as the number of distracters increase, the number of false alarms will increase, but the number of targets remained constant so the number of misses should be constant. However, the experimental procedure was to ignore the remaining vehicles once a target was identified. Hence, the increase in false alarms will decrease the number of opportunities to classify the KC-10s and thus decrease both the opportunity for and number of misses.

Table 7. Performance Measurements.

HITL responses are compared to Soar, TTA, and CTA simulation responses.

	Number of False Alarms				Number of misses				Number of Trials
	Baseline		RTIC		Baseline		RTIC		
Condition	3	5	3	5	3	5	3	5	
PITL	3	13	3	8	0	0	0	0	40
SOAR	6	11	N/A	N/A	7	5	N/A	N/A	60
TTA	8	28	0	0	4	3	6	10	100
CTA	0	0	0	0	0	0	14	6	100

DISCUSSION

The Soar model of the Maverick strike mission was limited by that mission scenario in that it forced the model to overemphasize the perceptual aspect of human cognitive performance. The model did demonstrate Soar's ability to perform discrete event simulations, but the model did not meaningfully employ Soar's ability to represent the more sophisticated aspects of human cognitive processing. For this reason, this discussion will focus less on the present model's capabilities and look forward to future application of Soar to cognitive modeling. The discussion will first identify classes of events which cognitive models must accurately predict. Second, experiments which utilize the cognitive aspect of the Soar architecture for modeling human cognition, including human limitations and human errors, will be identified. Third, we shall discuss how to compare competing human performance models. Finally, how to compare a cognitive model's predictions with human performance will be discussed.

Choosing Tasks Suitable for Cognitive Modeling

The Maverick mission biased the model toward the perception process since the task required the pilot to pick a vehicle to strike based on various sensory resources provided in the two cockpit configurations being tested. The mission characteristics drove the model toward a perceptual detection-identification cycle dependent on the range-to-target and the cockpit information display characteristics. The augmented configuration cockpit with overhead imagery eliminated the recognition part of the pilot's

task, making earlier firing decisions possible. The attack ranges were determined by the ability to detect individual targets in the target clusters. Although perception is part of human cognition, it is perhaps the best understood and the least demanding aspect of cognitive modeling. According to the Soar information processing model, perceptual information is fed into short-term memory store where it is processed in combination with long-term memory to enable the human operator to make decisions and take action to accomplish the required goals. The pilot's post-perception cognitive processing for the Maverick mission was trivial (since target vehicle recognition was achieved when enough pixels were available to support pilot perception of the targets) because there were no demanding additional cognitive processes to launching the Maverick missiles.

Tasks suitable for development and testing of cognitive models must exercise most if not all aspects of cognitive processing, including perception, assimilation into short-term memory, consolidation with long-term storage information, decision processes, and the motor response. Thus, choice of the task to be modeled is absolutely critical to developing and testing the modeling process. Test tasks should also permit a variety of alternative operator actions. Particular actions may "mark" the presence of specific cognitive response generation processes. Additionally, post-performance debriefings may reveal more information about the cognitive processes underlying subject action. Thorough test tasks can be developed in two ways: a single full-task which thoroughly tests all aspects of cognition or part-tasks which test specific separate aspects of cognition.

Consider one thorough full-task based on the existing Maverick strike mission that would span all the levels of cognitive processing. This task would require perception of critical information, integrating the new information with existing knowledge, using the combination to make a decision, and the resulting physical response. First, modify scenarios such that high value targets (KC-10s) are not present at every attack; hence, the pilot needs to decide whether to break-off the attack. This would modify the detect-recognize loop to include a decision whether or not to fire. The scenario can be further elaborated by locating the target not just among war planes where an error has little consequence, but civilian transports that may or may not contain passengers. Now

the detect-recognize-decision loop requires greater perceptual precision (capture of more details about the aircraft), additional information from long term storage (a wider range of aircraft types), and the fire decision must consider collateral damage.

The part-task alternative approach would consist of a series of unrelated tasks, each testing a different aspect of cognition process separately. This approach allows dissection of the cognitive process, but sacrifices the opportunity to study complex interactions among the levels. In this fashion, the Maverick mission which tests perceptual modeling would be augmented with events that would separately test other aspects of cognition. During egress from the target area a pop-up threat may appear that requires a decision about how to avoid it. A system emergency may occur which requires weapon system knowledge and integration of prior knowledge.

Multiple decisions are another way in which the cognitive complexity of the modeling test task can be increased. When operators must trade-off outcomes in two or more processes, as often is the case in real life tasks, the cognitive model can be tested under more realistic circumstances. This can be illustrated in our Maverick mission by the addition of terminal defenses in the target area. The original mission had the pilot fly unopposed into the target area. The presence of terminal defenses would add increasing risk with greater proximity to the targets. The range of this risk would depend on the aircraft threat warning system, pilot understanding of threat characteristics and mission priority. Parallel processing of the threat problem further complicates the cognitive processing demands on the pilot or model and puts greater load in the latter stages (information, integration and decision) of the cognitive process.

If cognitive modeling intends to predict human operator performance, models must respond to environmental stressors like their human counterparts. Models must be able to incorporate the effects of temporal pacing, effort, environmental stress (temperature, g-load, etc.), and fatigue. Combat environments are very different from the laboratory conditions, so that generalization is sometimes unjustified. Creating realistic models will require collecting data under as realistic conditions as possible.

Enhancing Soar's Similarity to Human Cognition

Newell (1987) intended Soar to perform cognition in a way similar to that of human cognition. However, the existing Soar architecture only partially achieves this goal. Although, in principle--Soar functions in a human-like fashion, its computational representations of working and long-term memory are far more powerful than their human counterparts. Soar's departures from human cognition are well understood. Working memory is meant to function like short-term memory, but working memory has unlimited capacity while human short-term memory has considerably less capacity (Miller, 1957). Soar's knowledge base is permanent, monolithic, and represented as rules and their firing conditions belying its artificial intelligence production system origins. Human knowledge is much more complex, marked by imperfect retrieval, representations varying over time, interactions with sensory modalities, and configured into non-uniform schemata (Neisser, 1976). Soar must be further anthropomorphized for it to accurately model human cognitive performance.

Dr. Laird at University of Michigan (personal communication), a project consultant, has identified several ways that the Soar architecture can be exploited to make its information processing more anthropomorphic. The changes Laird suggests do not alter Soar's basic function. The changes modify the contents of working memory or change rule processing to mimic known human processing characteristics.

The first proposed change is meant to mimic high stress or workload conditions. Human error rates increase under such conditions while unmodified Soar processing is unaffected. The change involves the withdrawal of rules from working memory to mimic changes in short-term memory under stress. Those withdrawn rules would not fire and the resulting decisions would not be based on all the available information. A critical issue for withdrawing rules is choosing which to remove. Random withdraw is one way. Another way is to track the frequency of past firings and lose less frequently firing rules first.

Second, Laird proposes limiting the number of productions fired in parallel under stress or workload. This would reduce the throughput of cognitive processing and

make cognition more of a sequential than a parallel process. Human ability to perform dual tasks simultaneously is limited and affected by the nature of the tasks (Wickens, Sandry & Vidulich, 1993).

A third method for anthropomorphizing Soar is to limit the cascades of production firing during the elaboration/decision cycle. The elaboration/decision cycle now considers the consequences of every potential firing on every other firing before making decisions. Human decision makers are typically not as thorough in testing the consequences of each decision and consequently make errors based on the failure to predict the broader consequences of their decisions. Limiting cascades of firings will increase Soar errors, but it remains to be seen whether these errors mimic those made by human operators.

The next two alterations of Soar function deal as much with the supporting computational environment as they do with Soar itself. Laird suggests artificially restricting execution speed, so as to prevent Soar from thoroughly processing the inputs in the available time. Pilots in the HITL simulation had only moments to detect and recognize the strike targets; under less time pressure they probably could have performed better. Soar, running on a fast computer might be able to process more information in the allotted time compared to its human counterpart. The IBM chess program Deep Blue beat a human competitor by thoroughly searching alternative courses of action faster and more accurately than its human opponent.

Another way processing speed can be limited is by adding additional tasks to reduce the processing time available for the cognitive processing. Pilots devote significant mental effort to flying their aircraft, a process that competes with available resources to detect, identify, and strike their targets. This siphoning of cognitive capacity is managed in two different ways in the design of strike aircraft. One design strategy is to include a second crew person dedicated to operating weapons. The F-15E Strike Eagle has a two person crew, one of whom is a dedicated weapon systems officer. The other design strategy is to automate some of the tasks so that a single crew person can perform the whole mission. The F-117 Nighthawk opts for the latter method, automating flying while the pilot concentrates on operating the weapon systems. Loading

the processor with ancillary tasks to reduce Soar processing cycle times mimics the workload issue in humans. Furthermore, Soar's processing speed must be matched to the amount of information a human operator can consider per the available processing time. Either the restriction of execution speed or the addition of competing tasks will require empirical studies to determine how much elaboration cycle time for any given Soar-hardware implementation are comparable to human performance and how elaboration cycle time may vary with training and experience.

The last potential modification to Soar to increase its similarity to human cognition is to vary the design of its knowledge base. The form, organization, and order of the rules with which Soar operates on its perception is central to cognitive processing. Neisser (1976) discusses the role of schemata or the organization of knowledge in the cognitive process. Hutchins (1995) further shows how very different schemata can be employed to support the same behavior, in his case, vessel navigation. In a simple form, novice behaviors can be compared to expert behaviors based on the depth and organization of their knowledge bases. However, more subtle differences in the knowledge base may provide greater understandings of Soar model behavior and ultimately human behavior.

Making Comparisons Among Competing Cognitive Models

This was one aspect of the current modeling effort that was very well managed by the Air Force Research Laboratory. Both the HITL and EADSIM data collections preceded development of the Soar model, so our Soar development team was kept blind to the earlier efforts. Only the particulars about the Maverick mission, and the dependent variables used to measure their performance, were provided during model development and testing. The results of the other efforts were made available only after the model data collection was completed.

There was one minor error in the information transfer for preparing the model. We were told that pilots could not release their Maverick before reaching the weapon's maximum range of 57,000 yards. The Soar model was programmed to incorporate this constraint, despite the fact in some conditions the decision to fire was made long before

the aircraft reached that distance from the target. The Soar model was programmed to delay weapons release until reaching the Maverick's maximum range. Unknown to our modeling team, pilots in the HITL simulation often released their missiles before reaching the missile envelope limits. This erroneous behavior is understandable because the decision to fire was made so much earlier in the approach, especially in the enhanced cockpit condition. This oversight produced an artificially induced discrepancy in weapon release range between the Soar model and the HITL simulation results. Clearly, equivalent behaviors were thwarted by not enforcing the Maverick missile release envelope during the HITL simulation.

The simplicity of the Maverick mission did not afford opportunity to explore comparative measures between models or error analysis. Multiple model runs can be used to determine probabilities of specific errors that could be compared across competing models. The types and conditions under which errors occur are a substantial basis for judging model fidelity. Error analysis could be further expanded, at least in Soar, to look at the antecedent conditions to committing the error. Soar can record the operations of its elaboration/decision cycle so that runs resulting in errors can be dissected to determine why the errors occurred.

Comparison of Cognitive Models to Human Performance

The true potential utility of cognitive modeling comes in its comparison to human performance. Early comparisons will largely be made to tune the fidelity of Soar based models and other modeling methods. Most of these comparisons will be like the ones described above between different cognitive models. Comparative dependent measures will be identified and the differences between model and human performance will be made much as it has been done here for the Maverick mission. Once the models have been tuned to mimic their human counterparts, cognitive models will be ready to serve as the first significant tools for cognitive engineering.

Engineering involves the systematic application of codified knowledge to permit design of systems with confidence in the ultimate performance. What has previously passed as cognitive engineering has been nothing more than artful application of cog-

nitive science to the system design process. Cognitive information has not been codified sufficiently to allow its application in a systematic fashion. Thus, cognitively derived designs lack our confidence and sometimes do not out perform traditional designs. Cognitive models may codify our knowledge in such a way to allow reliable prediction about a proposed design's ultimate performance.

Perhaps the most important use of cognitive models in the engineering process will be the discovery of design-based errors made by operators. Cognitive models can be used to conduct large numbers of mission simulations under wider ranges of conditions than are feasible with HITL simulations. Environmental stressors (like fatigue, temperature, terrain, weather), unusual events, and all combinations of system failures could be simulated sufficient numbers of times to identify and establish probabilities of errors as well as capture the rare combinations of events leading up to catastrophic failures. Furthermore, Soar models can provide the diagnostic information about how the cognitive events precipitate error. These failures could be verified by programming their antecedent events into HITL simulations to validate the cognitive modeling results. These kinds of error analyses could be powerful predictive tools for cognitive engineers, enabling virtual test of system interface designs before they are actually implemented. Cognitive models hold the potential to put the engineering into cognitive engineering.

RECOMMENDATIONS

The present modeling effort establishes that Soar can model the same kinds of tasks that discrete event models can, and with an enhanced perceptual representation perform as well or better than discrete event simulations like EADSIM. The particular mission given to be modeled did not exercise Soar's cognitive modeling capabilities beyond the perceptual capabilities. The principle recommendation is that Soar should be applied to more cognitively demanding tasks, either tasks that span multiple features of cognitive processing or suites of tasks that focus on particular aspects of cognitive processing.

Perhaps the best way to approach creating a comprehensive cognitive model is to model "slices" of cognitive behavior (the part-task approach) which are constrained

by limited input, outputs, and event complexity. Such limited models could serve as test beds where the effects of the anthropomorphizing modifications could be tested and compared with similarly constrained, HITL simulations. These limited scope models should be designed so that they could be linked either in serial or later in parallel so that interactions in their operations can be compared to their earlier function in isolation. In this fashion, a more comprehensive model of operator function could be built while exploring the basic science issues of modeling human cognition.

Model elaboration would eventually produce a comprehensive model of a human operator that could be tested in a fashion suitable for cognitive engineering predictions of performance. More complex event scripts and more cognitive demanding events could be introduced so that the error analysis discussed earlier could be performed. In this way, definitive predictions could be made about where human errors can be anticipated and the antecedent events could be used to prepare HITL simulations to discover the hypothesized error points. Data could also be recovered from devices like flight recorders or from accident investigations to determine whether the predicted errors are encountered in real systems. The ultimate goal of such efforts would be to create an engineering procedure by which operator stations can be thoroughly modeled and tested so that cognitive engineering becomes less of an art and more of an engineering science.

APPENDICES

1.1 Final Data

1.2 Complete Set of Pixelated Views of KC-10 and B-52

1.3 Selected Text Output from Baseline Condition

1.4 Selected Text Output from the RTIC Condition

1.5 Snapshot of Plane Firing on Targets

1.6 ANOVA Results

1.7 Soar Code

Appendix 1.1

Final Data

TIC-3	FINAL DATA											
	accuracy				first detection			first ID			first designation		
trial number	hits	miss	fa	cr	time	range	range to airfield	time	range	to airfield	time	range	range to airfield
average	2.00	0.00	0.00	1.80	10.53	93537	95173	0	0	0	12.75	91690	93589
stdv	0.00	0.00	0.00	1.30	4.39	2980	3644	0	0	0	4.57	3228	3759
1	2	0	0	2	3	96374.1	100656	0	0	0	6	93675.7	98616.7
2	2	0	0	3	18	89793.8	88531.5	0	0	0	21	86406.9	86738
3	2	0	0	3	11	90993.8	95262.6	0	0	0	14	87849.5	92793.8
4	2	0	0	2	7	94964.3	98170.8	0	0	0	10	92810.2	95882.3
5	2	0	0	1	7	94918.4	97721.7	0	0	0	9	93646.2	96721.7
6	2	0	0	2	13	92833.1	92869.2	0	0	0	14	92183.9	92502
7	2	0	0	4	13	88475.7	93128.2	0	0	0	17	85921.6	90469.2
8	2	0	0	1	7	93728.2	98203.6	0	0	0	9	92498.7	97046.2
9	2	0	0	2	8	92203.6	96865.9	0	0	0	12	88918.3	93465.9
11	2	0	0	3	15	88505.2	91685.6	0	0	0	18	86423.3	89485.6
12	2	0	0	1	10	92272.5	95469.2	0	0	0	12	90931.5	93997.1
14	2	0	0	1	13	93659.3	93111.8	0	0	0	14	92744.6	92472.5
51	2	0	0	4	6	94010.2	98285.6	0	0	0	9	91485.6	96429.9
52	2	0	0	0	3	97272.5	101948	0	0	0	4	96121.6	101066
53	2	0	0	1	3	97203.6	101486	0	0	0	5	94849.5	99790.5
54	2	0	0	1	8	94620	97420	0	0	0	9	93557.7	96629.9
55	2	0	0	2	6	95816.7	99026.6	0	0	0	9	93626.6	96698.7
56	2	0	0	4	17	90456.1	89898.7	0	0	0	20	88334.7	87538
57	2	0	0	4	11	90462.6	94928.2	0	0	0	14	88485.6	93036.4
58	2	0	0	0	13	92692.1	92311.8	0	0	0	15	91465.9	91367.5
59	2	0	0	1	3	96367.6	101043	0	0	0	5	95259.4	99806.9
60	2	0	0	1	10	95731.5	95783.9	0	0	0	15	92042.9	91947.9
61	2	0	0	0	14	92633.1	92085.6	0	0	0	15	91590.5	91318.4
62	2	0	0	1	13	93059.3	92679	0	0	0	15	91446.2	91344.6
99	2	0	0	3	9	93597.1	96400.3	0	0	0	11	91639.7	94715.1
100	2	0	0	0	3	97082.3	101758	0	0	0	4	95947.9	100889
101	2	0	0	1	15	92357.7	91285.6	0	0	0	17	91000.3	90206.9
102	2	0	0	0	7	95721.6	98524.9	0	0	0	8	94839.7	97911.8
103	2	0	0	2	10	95757.7	95216.7	0	0	0	12	94685.6	93892.1
104	2	0	0	3	14	92974.1	92423.3	0	0	0	17	90711.8	89918.4
105	2	0	0	1	10	91983.9	96252.8	0	0	0	11	90688.8	95239.7
106	2	0	0	0	15	91492.1	91108.5	0	0	0	16	90747.9	90649.5
107	2	0	0	1	13	94213.4	93669.2	0	0	0	14	93092.1	92823.3
108	2	0	0	0	14	93167.5	92793.8	0	0	0	15	91846.2	91751.1
109	2	0	0	0	5	100499	99970.8	0	0	0	6	99479	99210.2
110	2	0	0	2	16	91302	90223.3	0	0	0	19	88426.5	88154.4
147	2	0	0	2	9	93856.1	97059.4	0	0	0	11	92397	95465.9
148	2	0	0	0	6	94416.7	99082.3	0	0	0	7	93403.6	98344.6
149	2	0	0	3	12	90108.5	94574.1	0	0	0	15	86997	91938
150	2	0	0	1	12	94344.6	94397.1	0	0	0	13	93170.8	93498.7
151	2	0	0	1	16	87682.3	90452.8	0	0	0	18	85833.1	88902
152	2	0	0	4	15	91262.6	90708.5	0	0	0	18	89679	88885.6
177	2	0	0	2	17	87557.7	90334.7	0	0	0	19	85446.2	88511.8
178	2	0	0	1	6	99295.4	99357.7	0	0	0	8	97941.3	97843
179	2	0	0	3	9	91531.5	96000.3	0	0	0	12	89728.2	94275.7
180	2	0	0	4	11	94702	94751.2	0	0	0	15	91770.8	91675.7
181	2	0	0	2	13	93521.6	92974.1	0	0	0	14	92869.2	92597
182	2	0	0	3	19	89370.8	88285.6	0	0	0	22	86633.1	86361
220	2	0	0	0	3	96587.2	101259	0	0	0	4	95429.8	100371
221	2	0	0	2	18	90774.1	89505.2	0	0	0	20	87702	88023.3
226	2	0	0	3	5	100584	99800.4	0	0	0	8	98374.1	97577.4
227	2	0	0	1	10	95672.5	95728.2	0	0	0	11	95059.4	95387.2
228	2	0	0	0	18	90383.9	89305.2	0	0	0	19	89302	88508.5
229	2	0	0	3	12	94741.3	93482.3	0	0	0	14	91902	92223.3
230	2	0	0	3	12	90862.6	94052.8	0	0	0	15	88951.1	92016.7
231	2	0	0	3	7	93423.3	98092.1	0	0	0	10	91459.3	96010.2
232	2	0	0	3	11	95761	94964.3	0	0	0	14	92613.4	92344.6
233	2	0	0	2	7	98554.4	97305.3	0	0	0	12	93872.5	93770.8
234	2	0	0	4	12	90879	94072.5	0	0	0	15	89220	92282.3
235	2	0	0	1	9	97167.6	96629.9	0	0	0	10	96252.8	95983.9

RTIC-3						FINAL DATA					
second designation			first lock			second lock			launch		
time	range	range to airfield	time	range	range to airfield	time	range	range to airfield	time	range	range to airfield
18.25	87352	89149	21.25	85118	86712	22.25	84408	85897	54.78	57894	59332
4.47	4285	3667	4.47	3377	3640	4.47	4263	3654	2.71	36	2247
10	92439.7	95511.8	13	88436.4	93085.6	14	89511.8	92295.4	51	57862.5	62357.6
27	76806.8	81754.4	30	79469.1	79472.4	31	74023.2	78620	56	57915	57777.3
19	89547.9	88754.4	22	81442.9	86069.2	23	86642.9	85551.1	51	57915	62410.1
14	92374.1	92698.7	17	87679	90456.1	18	89413.4	89446.2	54	57905.1	60492
16	91895.4	91102	19	85842.9	88613.4	20	88934.7	87849.5	53	57842.8	60436.3
22	86872.4	86079	25	83426.5	83429.8	26	84020	82918.3	57	57829.7	57675.6
23	82705.2	85767.5	26	79039.6	83262.6	27	79642.9	82380.6	52	57957.6	62062.5
13	93849.5	93754.4	16	86764.2	91016.7	17	90468.8	90102	52	57846.1	61947.8
17	90026.5	89757.7	20	82898.7	87134.7	21	86931.5	86361	51	57924.8	62026.4
23	85515.1	85416.7	26	80124.9	82862.6	27	82767.5	82351.1	54	57875.6	60469.1
16	90938	90669.2	19	85492.1	88259.3	20	87915.1	87351.1	53	57908.4	60508.4
19	88544.6	88442.9	22	86672.4	86101.9	23	85498.7	85092.1	57	57898.6	57174
15	88459.3	91528.2	18	84383.9	89020	19	85495.4	88259.3	51	57875.6	62370.7
11	95121.6	95446.2	14	88233.1	92882.3	15	92259.3	92302	51	57957.6	62456
15	92502	91708.5	18	84790.5	89429.8	19	89685.6	88600.3	51	57905.1	62400.2
14	92380.7	92702	17	87511.8	90285.6	18	89479	89511.8	53	57918.2	60508.4
16	91849.5	91056.1	19	85911.8	88679	20	88888.8	87803.6	53	57908.4	60498.6
26	82531.4	82849.5	29	81698.6	80587.2	30	79787.2	79774.1	58	57842.8	56600.2
20	84961	88023.3	23	81544.5	85777.4	24	82226.5	84977.4	52	57915	62019.9
19	83410.1	87961	22	86095.4	85692.1	23	80574.1	84800.3	57	57882.2	57305.1
9	96649.5	96380.7	12	89511.8	93774.1	13	93829.8	93288.9	51	57875.6	61977.3
19	85639.6	88705.2	22	86357.7	85957.7	23	82547.8	85298.7	57	57908.4	57334.6
19	85111.8	88174.1	22	86328.2	85757.7	23	82095.4	84842.9	57	57937.9	57216.6
20	87633.1	87361	23	85410.1	85000.3	24	84626.5	84049.5	57	57924.8	57347.7
17	85079	90016.7	20	84734.7	87505.2	21	82085.5	86708.5	53	57865.8	60462.5
8	97403.6	97728.2	11	90577.4	95236.4	12	94403.6	94452.8	51	57941.2	62436.3
22	81282.3	86223.3	25	84944.6	83846.2	26	78344.5	82954.4	58	57957.6	56715
13	93462.6	93787.2	16	88688.8	91465.9	17	90452.8	90488.8	54	57878.9	60465.8
18	85751.1	88816.7	21	87564.2	86475.7	22	82911.8	85665.9	58	57888.7	56646.1
22	85551.1	85872.4	25	84659.3	83561	26	82672.4	82675.7	58	57862.5	56619.9
16	88259.3	91324.9	19	84744.6	88990.5	20	85249.5	88013.4	52	57859.2	61960.9
20	82905.2	87456	23	85357.7	84947.8	24	79892.1	84115.1	57	57911.7	57334.6
19	84190.5	88738	22	86918.3	86351.1	23	81095.4	85328.2	58	57908.4	57187.1
19	85410.1	88472.4	22	86656	86256	23	82685.5	85436.4	57	57839.5	57265.8
10	92869.2	95934.8	13	94079	93531.5	14	89629.8	92410.2	57	57898.6	57177.2
23	85069.2	84964.2	26	83075.7	82492.1	27	81911.8	81488.8	57	57898.6	57177.2
16	86492.1	91433.1	19	86183.9	88951.1	20	83347.8	87980.6	54	57849.4	60436.3
18	89249.5	89564.2	21	82269.1	86895.4	22	86262.6	86275.7	51	57852.7	62344.5
20	88842.9	88049.5	23	80813.4	85436.4	24	85574.1	84479	51	57869.1	62364.2
18	86492.1	89551.1	21	86915.1	86941.3	22	83397	86147.8	57	57872.3	57728.1
22	86547.8	85754.4	25	80675.7	83416.7	26	83616.7	82511.8	53	57924.8	60515
24	83790.5	84105.2	27	82852.8	81744.6	28	80862.6	80856	58	57951	56708.4
24	80121.6	84672.4	27	79597	82334.7	28	77269.1	81485.5	54	57898.6	60495.3
12	90062.6	94610.2	15	92498.7	92121.6	16	87088.8	91341.3	58	57833	57259.2
20	87967.5	87695.4	23	81026.5	85256	24	85085.5	84508.5	51	57944.5	62046.1
21	83711.8	86774.1	24	84941.3	84531.4	25	80869.1	83610.1	57	57937.9	57364.1
20	84593.7	87656	23	85708.5	85134.7	24	81620	84364.2	57	57842.8	57121.5
27	82544.6	82442.9	30	80403.6	79806.8	31	79456	79023.2	58	57872.3	57151
11	91754.4	94823.3	14	87665.9	92315.1	15	88744.6	91524.9	51	57852.7	62347.8
25	79052.7	83993.7	28	81498.6	81495.4	29	76019.9	80623.2	57	57846.1	57698.6
13	88747.9	93688.9	16	92216.7	91141.3	17	85875.7	90518.4	58	57855.9	56613.3
16	88029.8	91095.4	19	88865.9	88895.4	20	85295.4	88056	57	57921.5	57774
23	81970.8	85033.1	26	84242.9	83141.3	27	79210.1	81944.6	58	57941.2	56698.6
20	88180.6	87387.2	23	84918.3	84928.2	24	85380.6	84282.3	56	57928.1	57777.3
20	83472.4	88023.3	23	82541.3	85288.8	24	80400.3	84626.5	54	57888.7	60482.2
22	86301.9	86203.6	25	79652.7	83879	26	83501.9	83088.8	52	57895.3	61996.9
19	83898.7	88449.5	22	86501.9	85931.5	23	80918.3	85151.1	57	57944.5	57219.9
16	87347.9	90416.7	19	88557.7	88161	20	84669.1	87433.1	57	57915	57337.9
21	87387.2	87115.1	24	81993.7	84741.3	25	84646.2	84069.1	54	57849.4	60442.8
18	89580.6	89482.3	21	87501.9	86934.7	22	86724.9	86324.9	58	57882.2	57160.9

TIC-5	FINAL DATA												
	accuracy				first detection			first ID			first designation		
trial number	hits	miss	fa	cr	time	range	range to airfield	time	range	range to airfield	time	range	range to airfield
average	2.00	0.00	0.00	3.80	10.10	93806	95613	0	0	0	13.90	90554	92727
stdv	0.00	0.00	0.00	1.86	4.61	3459	3793	0	0	0	5.14	3610	4179
15	2	0	0	5	12	91331.5	93636.4	0	0	0	18	86659.3	89452.8
16	2	0	0	5	9	92377.4	96174.1	0	0	0	12	89262.6	94206.9
17	2	0	0	5	10	96285.6	95488.9	0	0	0	13	93967.5	93174.1
249	2	0	0	2	6	97029.9	99561	0	0	0	7	95918.4	98711.8
19	2	0	0	4	9	94049.5	96846.2	0	0	0	14	90082.3	92872.5
20	2	0	0	5	13	93944.6	93141.3	0	0	0	17	90610.2	89816.7
21	2	0	0	5	11	91842.9	95039.7	0	0	0	14	89724.9	92518.4
22	2	0	0	1	13	89357.7	93315.1	0	0	0	14	88252.8	92498.7
23	2	0	0	3	7	94111.8	97911.8	0	0	0	10	91344.6	95590.5
24	2	0	0	2	17	87423.3	90190.5	0	0	0	19	86249.5	89036.4
25	2	0	0	6	12	91541.3	94331.5	0	0	0	17	87334.7	90124.9
26	2	0	0	4	20	88488.8	87924.9	0	0	0	24	84338	84583.9
63	2	0	0	3	11	91790.5	94583.9	0	0	0	14	89761	92554.4
64	2	0	0	2	10	91511.8	96174.1	0	0	0	11	90446.2	95390.5
65	2	0	0	4	10	91702	95495.4	0	0	0	15	87098.7	92042.9
66	2	0	0	4	13	93518.4	93144.6	0	0	0	18	89324.9	89649.5
67	2	0	0	5	9	94229.8	97026.6	0	0	0	14	90374.1	93167.5
68	2	0	0	3	15	92115.1	92157.7	0	0	0	16	90993.8	91318.4
69	2	0	0	6	11	90128.2	93918.4	0	0	0	15	87187.2	91433.1
70	2	0	0	4	3	97462.6	101276	0	0	0	6	94390.5	98639.7
71	2	0	0	4	3	97265.9	101548	0	0	0	10	91875.7	96121.6
72	2	0	0	3	3	98528.2	101748	0	0	0	6	96502	99298.7
73	2	0	0	4	11	95324.9	94783.9	0	0	0	19	88505.2	88754.4
74	2	0	0	7	19	89308.5	88747.9	0	0	0	24	84475.7	84724.9
111	2	0	0	3	12	91098.7	94295.4	0	0	0	16	88498.7	91288.8
112	2	0	0	2	3	96990.5	101663	0	0	0	4	95938	100879
113	2	0	0	2	6	95265.9	99239.7	0	0	0	8	92711.8	97652.8
114	2	0	0	4	15	92443	92121.6	0	0	0	18	89269.2	89593.8
115	2	0	0	4	8	97918.4	97652.8	0	0	0	16	91629.8	90836.4
116	2	0	0	4	6	99013.5	98652.8	0	0	0	8	96849.5	97170.8
117	2	0	0	3	8	91662.6	96324.9	0	0	0	11	90328.2	94577.4
118	2	0	0	7	4	97318.4	101128	0	0	0	11	91052.8	95298.7
119	2	0	0	3	11	95931.5	94865.9	0	0	0	14	92629.8	92879
120	2	0	0	4	7	98436.4	98134.8	0	0	0	9	96944.6	96852.8
121	2	0	0	2	17	89941.3	89902	0	0	0	18	89144.6	89393.8
122	2	0	0	4	7	98747.9	98003.6	0	0	0	21	87187.2	87088.8
183	2	0	0	0	7	94079	98744.6	0	0	0	8	92964.3	97905.3
184	2	0	0	6	6	99233.1	98938.1	0	0	0	9	96197.1	96521.7
185	2	0	0	1	7	94121.6	97924.9	0	0	0	10	90642.9	95583.9
186	2	0	0	1	11	92557.7	95072.5	0	0	0	12	91534.8	94324.9
187	2	0	0	7	7	94941.3	97747.9	0	0	0	13	90134.7	92928.2
188	2	0	0	6	11	95305.3	94997.1	0	0	0	16	90964.3	91288.8
189	2	0	0	6	7	93331.5	98000.3	0	0	0	16	87144.6	91393.8
190	2	0	0	2	3	97849.5	101830	0	0	0	4	96718.4	100964
191	2	0	0	5	9	97216.7	96157.7	0	0	0	17	89459.3	89711.8
192	2	0	0	4	4	98180.7	100994	0	0	0	8	94882.3	97675.8
193	2	0	0	2	16	91692.1	90882.3	0	0	0	19	88377.4	88626.5
194	2	0	0	6	10	94734.8	94783.9	0	0	0	16	90718.4	90616.7
236	2	0	0	8	16	86115.1	90564.3	0	0	0	21	81564.2	86505.2
237	2	0	0	4	5	94774.1	99446.2	0	0	0	6	94016.7	98961
238	2	0	0	4	16	90308.5	90272.5	0	0	0	22	86675.7	85882.3
239	2	0	0	5	12	94046.2	93675.7	0	0	0	16	90262.6	90587.2
240	2	0	0	1	8	98210.2	97154.4	0	0	0	9	97446.2	96652.8
241	2	0	0	4	21	87036.4	86636.4	0	0	0	23	85167.5	85485.5
242	2	0	0	2	20	84367.5	87131.5	0	0	0	22	82879	85672.4
243	2	0	0	1	8	93167.5	97138	0	0	0	10	92000.3	96249.5
244	2	0	0	0	5	95708.5	99685.6	0	0	0	6	94469.2	98715.1
246	2	0	0	7	12	94898.7	94141.3	0	0	0	16	91472.5	91377.4
247	2	0	0	5	9	97715.1	96656.1	0	0	0	15	91823.3	92072.5
248	2	0	0	3	15	93318.4	92059.3	0	0	0	19	88849.5	88751.1

RTIC-5					FINAL DATA						
second designation			first lock			second lock			launch		
time	range	range to airfield	time	range	range to airfield	time	range	range to airfield	time	range	range to airfield
20.55	85911	87350	23.55	83059	84918	24.55	82957	84082	54.43	57909	59623
4.51	4441	3666	4.51	3388	3689	4.51	4427	3674	2.64	37	2064
23	80147.8	85092.1	26	80521.6	82990.5	27	77501.9	82108.5	54	57908.4	60236.3
21	86652.8	86977.4	24	79964.2	84583.9	25	83833.1	83846.2	51	57921.5	62419.9
20	82479	87420	23	86187.2	85095.4	24	79377.3	83993.7	58	57892	56649.4
13	93380.7	93708.5	16	89006.9	91508.5	17	90305.2	90344.6	54	57921.5	60239.6
20	88813.4	88020	23	83141.3	85616.7	24	85738	84639.6	54	57918.2	60239.6
23	84656	84974.1	26	83134.7	82029.8	27	81305.2	81301.9	58	57833	56590.4
21	82757.7	87003.6	24	82147.8	84626.5	25	79685.5	83606.9	54	57937.9	60262.5
19	88570.8	88472.4	22	82010.1	85941.3	23	85577.4	85174.1	52	57849.4	61646.1
15	91285.6	91534.8	18	84970.8	88911.8	19	88233.1	88187.2	51	57905.1	61701.9
24	84990.5	84895.4	27	80147.8	82610.1	28	81892.1	81475.7	54	57859.2	60177.3
23	85079	85328.2	26	80452.7	82918.3	27	82088.8	82023.2	54	57947.7	60272.3
29	80734.7	80633.1	32	77872.4	77787.2	33	77865.9	77429.6	57	57855.9	57646.1
19	83629.8	88570.8	22	83701.9	86187.2	23	80528.2	85147.8	54	57947.7	60272.3
19	88580.6	88908.5	22	81659.3	86288.8	23	85646.2	85669.2	51	57954.3	62449.4
19	89485.6	88692.1	22	81577.3	86203.6	23	86449.5	85354.4	51	57878.9	62374
22	83646.2	86433.1	25	83977.3	83990.5	26	80410.1	82872.4	57	57878.9	57731.4
20	89029.8	88236.4	23	83020	85495.4	24	86111.8	85016.7	54	57908.4	60229.7
23	86361	85567.5	26	83298.7	83308.5	27	83642.9	82541.3	57	57905.1	57764.1
22	82993.7	85783.9	25	79383.9	83305.2	26	79960.9	82426.5	51	57869.1	61669.1
12	93934.8	93839.7	15	87403.6	91354.4	16	91026.6	90642.9	51	57954.3	61754.3
14	92465.9	92718.4	17	86393.8	90341.3	18	89636.4	89600.3	52	57865.8	61662.5
11	95210.2	95115.1	14	90256.1	92764.3	15	92302	91924.9	54	57957.6	60282.2
24	81957.7	84741.3	27	82305.2	82239.6	28	78862.6	81318.3	57	57908.4	57701.8
31	79029.8	78928.1	34	76692.1	76600.3	35	76305.2	75862.6	57	57944.5	57737.9
20	83177.3	88121.6	23	83210.1	85692.1	24	80269.1	84888.8	54	57941.2	60265.8
15	91410.2	91731.5	18	84941.3	89577.4	19	88721.6	88751.1	51	57918.2	62413.3
18	90180.6	89387.2	21	82390.5	87020	22	87462.6	86374.1	51	57908.4	62403.5
25	81138	83924.9	28	81728.2	81728.2	29	78098.6	80554.4	57	57875.6	57728.1
21	84069.1	86859.3	24	85934.7	84839.6	25	81505.2	83977.3	58	57869.1	56626.4
15	92288.9	91495.4	18	88977.4	89003.6	19	89229.8	88144.6	56	57944.5	57796.9
16	87816.7	90606.9	19	84193.7	88131.5	20	84892.1	87377.4	51	57934.6	61731.4
20	88108.5	88013.4	23	81724.9	85652.8	24	85200.3	84797	52	57895.3	61695.3
19	84593.7	88842.9	22	86521.6	86472.4	23	81685.5	85613.4	57	57846.1	57636.3
19	86157.7	88944.6	22	86626.5	86229.8	23	83000.3	85475.7	58	57951	57383.8
24	81662.6	84449.5	27	82177.3	82111.8	28	78905.2	81364.2	57	57918.2	57708.4
26	82642.9	82888.8	29	80964.2	80541.3	30	79642.9	79564.2	57	57836.3	57265.8
13	90997	93790.5	16	86711.8	91357.7	17	88121.6	90620	51	57951	62446.1
17	84990.5	89931.5	20	87590.5	87613.4	21	82006.8	86633.1	56	57951	57803.5
14	93400.3	92606.9	17	85442.9	90082.3	18	90170.8	89092.1	51	57905.1	62400.2
17	89987.2	90311.8	20	85485.5	87974.1	21	87220	87246.2	54	57934.6	60259.2
21	87252.8	86459.3	24	81656	84131.4	25	84092.1	82990.5	53	57872.3	60196.9
22	87354.4	86561	25	83888.8	83901.9	26	84393.7	83292.1	57	57839.5	57695.3
22	83554.4	86338	25	80118.3	84042.9	26	80810.1	83275.7	52	57937.9	61737.9
14	92875.7	92780.7	17	86433.1	90380.6	18	89879	89495.4	52	57915	61715
24	79810.1	84056	27	81469.1	81400.3	28	77118.3	81029.8	56	57954.3	57747.7
21	87442.9	87344.6	24	82393.7	84869.2	25	84505.2	84098.7	54	57957.6	60278.9
23	82659.3	85446.2	26	83115	83052.8	27	79859.3	82321.6	57	57865.8	57655.9
22	85541.3	85790.5	25	83793.7	83380.6	26	82334.7	82272.4	57	57908.4	57328.1
29	77246.2	80036.4	32	73056	77642.9	33	74315	76754.4	50	57924.8	62416.6
22	85767.5	86088.8	25	78990.4	83606.9	26	82842.9	82849.5	51	57846.1	62341.2
26	77990.4	82931.4	29	81505.2	80390.4	30	74938	79534.7	58	57954.3	56715
22	82901.9	85692.1	25	83193.7	83200.3	26	79990.4	82456	56	57941.2	57790.4
14	89961	92754.4	17	91511.8	90433.1	18	86905.2	89403.6	58	57859.2	56616.6
30	80675.7	79882.2	33	77439.6	77419.9	34	77583.9	76456	57	57941.2	57790.4
27	77419.9	81665.9	30	76938	79390.4	31	74626.5	78524.9	53	57934.6	60259.2
17	90465.9	90370.8	20	84183.9	88121.6	21	87606.9	87210.1	52	57944.5	61744.5
22	85983.9	86233.1	25	79823.2	83744.6	26	82774.1	82711.8	52	57901.8	61701.9
24	82151.1	84941.3	27	82620	82206.9	28	79242.9	81705.2	58	57908.4	57337.9
22	83649.5	86433.1	25	83990.5	83928.2	26	80711.8	83177.3	57	57937.9	57728.1
23	85436.4	85685.5	26	83544.6	83134.7	27	82469.1	82403.6	58	57882.2	57311.7

BASELINE-3 FINAL DATA

trial number	accuracy				first detection			first ID			first designation		
	hits	miss	fa	cr	time	range	range to airfield	time	range	range to airfield	time	range	range to airfield
average	1.90	0.12	0.10	2.05	9.97	94522	95716	44	67123	68195	46.47	64955	66435
stdv	0.30	0.32	0.30	1.23	4.82	3263	3934	4	1708	2901	3.90	1941	3188
27	2	0	0	4	12	89564.2	94026.6	43	64600.2	68951.1	46	61482.2	66426.5
28	2	0	0	0	14	92010.2	92049.5	47	65859.2	65770.7	48	64839.6	65147.8
29	2	0	0	0	18	90423.3	89341.3	50	64924.8	63731.4	51	63613.3	62819.9
30	2	0	0	1	10	96911.8	95662.6	46	68229.8	66856	48	64964.2	65275.6
31	2	0	0	2	9	93265.9	96469.2	42	66429.7	69501.9	45	63937.9	66983.8
32	2	0	0	1	14	92816.7	91744.6	47	66180.6	64993.7	49	64793.7	63996.9
33	2	0	0	1	3	98075.8	100889	40	68816.6	71492.1	42	66701.9	69754.3
34	2	0	0	1	8	92747.9	97410.2	41	66157.6	70708.4	43	64856	69406.8
35	2	0	0	2	8	92820	97292.1	41	66203.5	70564.2	45	63354.3	67901.9
36	2	0	0	2	3	98456.1	101676	38	69947.8	73042.9	40	68688.8	71741.2
37	2	0	0	3	15	88944.6	92131.5	45	64236.3	67295.3	48	62233	65278.9
38	2	0	0	2	15	91324.9	91361	47	65456	65364.2	51	62918.3	62800.2
75	2	0	0	3	4	95679	100158	39	67701.9	72069.1	41	65997	70941.2
76	2	0	0	1	3	97220	101892	37	69656	74226.5	38	68656	73600.3
77	2	0	0	0	11	95829.8	94767.5	46	67682.2	66501.9	47	67003.5	66210.1
78	2	0	0	1	14	93856.1	92593.8	48	66692	65308.4	50	63364.2	63672.4
79	2	0	0	2	11	96108.5	95043	46	67878.9	66701.9	47	66708.4	65915
80	1	1	1	4	13	93334.8	93377.4	46	66505.2	66423.2	51	63616.6	62619.9
81	2	0	0	2	9	93577.4	96374.1	43	66554.3	69213.4	45	64813.3	67862.5
82	2	0	0	2	17	90279	90315.1	48	64908.4	64816.6	51	62911.7	62796.9
83	2	0	0	1	16	91275.7	90721.6	48	65429.7	64760.9	49	64262.5	63990.4
84	2	0	0	4	4	97518.4	100328	40	68570.7	71242.9	43	66124.8	69174
85	2	0	0	2	15	92662.6	91590.5	48	66197	65010.1	51	62859.2	62587.1
86	2	0	0	2	8	98377.4	97321.7	44	69042.9	67872.4	48	65551.1	65278.9
123	2	0	0	1	5	97016.7	99826.6	41	68275.6	70944.5	42	67075.6	70121.6
124	1	0	1	3	3	97272.5	101754	38	68472.4	72842.9	40	67206.8	71754.4
125	2	0	0	2	13	94170.8	93370.8	47	66918.3	66003.5	50	64252.7	63459.2
126	2	0	0	0	10	92613.4	95406.9	43	66078.9	68734.7	44	65311.7	68357.6
127	2	0	0	3	17	90383.9	89826.5	49	65033	64360.9	51	63826.5	63033
128	2	0	0	2	13	94397.1	93141.3	48	66941.2	65557.6	51	62806.8	63115
129	2	0	0	1	3	97357.7	101840	37	69816.6	74193.7	39	68019.9	72570.8
130	2	0	0	2	8	97482.3	97115.1	44	68577.3	68082.2	45	67462.5	67344.5
131	2	0	0	2	11	95583.9	94521.6	46	67570.7	66393.7	49	64701.9	64429.7
132	2	0	0	2	15	91970.8	92006.9	47	65803.5	65711.7	49	64803.5	64685.5
133	2	0	0	3	9	96967.6	95908.5	45	68269.1	67092	48	65085.5	64813.3
134	1	0	1	2	8	98006.9	96761	45	68813.4	67442.9	47	65485.5	65797
153	2	0	0	4	12	88767.5	93226.6	43	64226.5	68574	46	61334.6	66275.6
154	2	0	0	2	11	91075.7	95344.6	43	65364.2	69518.3	45	62954.3	67898.6
155	2	0	0	2	19	89482.3	88400.3	50	64554.3	63357.6	51	63518.3	62724.8
156	2	0	0	4	3	98111.8	101332	39	68869.1	71957.6	45	64646.1	67692
157	2	0	0	2	12	91220	94010.2	44	65505.1	68154.3	45	64737.9	67783.8
158	2	0	0	3	7	99180.7	98652.8	44	69367.5	68721.6	46	67869.1	67075.6
159	1	0	1	3	4	95747.9	100420	39	67767.5	72328.1	41	66203.5	70954.4
160	2	0	0	0	15	92164.3	91783.9	47	65859.2	65347.8	49	64308.4	64193.7
161	2	0	0	1	6	94646.2	99124.9	40	67115	71478.9	42	65695.3	70246.1
162	2	1	0	3	15	92151.1	91774.1	48	65934.7	65426.5	52	62229.7	62115
163	2	0	0	3	12	94849.5	93783.9	46	67269.1	66088.8	49	64292	64019.9
164	2	0	0	1	19	88554.4	88580.6	49	64078.9	63977.3	51	63029.7	62911.7
195	2	0	0	3	6	94387.2	98662.6	40	66990.4	71151.1	42	64931.4	69875.7
196	2	0	0	0	6	99449.5	99511.8	43	69410.1	69344.5	44	68537.9	68849.4
197	2	0	0	2	11	95679	94882.3	46	67701.9	66793.7	51	63574	62780.6
198	2	1	0	4	10	96282.3	95918.4	45	67937.9	67442.9	51	62557.6	62865.8
199	2	1	0	4	14	93551.1	92747.9	47	66547.8	65629.7	53	62059.2	61265.8
200	2	0	0	1	18	90292.1	89479	49	64885.5	63957.6	51	63390.4	62596.9
201	2	1	0	4	6	93944.6	98420	40	66728.1	71088.8	42	65059.2	69610.1
202	1	1	1	2	8	98213.5	96970.8	45	68892	67524.8	49	65426.5	64436.3
203	1	0	1	2	5	95613.5	100286	39	67646.1	72206.8	40	67013.4	71957.6
204	2	0	0	1	3	101387	101036	42	70515	70036.3	43	69406.8	69295.3
205	2	0	0	1	4	98033.1	100843	40	68790.4	71459.3	42	66977.3	70023.2
206	2	1	0	5	3	102256	101735	41	70980.6	70344.5	46	67265.8	66993.7

BASELINE-3						FINAL DATA					
second designation			first lock			second lock			launch		
time	range	range to airfield	time	range	range to airfield	time	range	range to airfield	time	range	range to airfield
51.72	59994	62164	54.72	58725	59759	55.73	57187	58899	57.93	56147	57159
3.37	3727	2767	3.37	1888	2771	3.38	3679	2739	3.14	1509	2510
52	59013.3	62052.7	55	55016.6	59485.5	56	56315	58888.7	58	52734.6	57183.8
52	57003.5	61947.8	55	59655.9	59518.2	56	54298.6	58764.1	58	57288.7	57131.3
55	54737.9	59682.2	58	58551	57315	59	52023.1	56469.1	61	56128.1	54872.3
52	58908.4	61941.2	55	59728.1	59596.9	56	56111.7	58682.2	58	57265.8	57115
50	64131.4	63337.9	53	58226.4	60819.9	54	61301.9	60085.5	56	56049.4	58623.2
55	58646.1	58947.8	58	57806.8	56560.9	59	55960.9	55790.4	61	55606.8	54344.5
46	61970.7	66518.3	49	61708.4	64337.9	50	59124.8	63236.3	53	57852.7	60446.1
48	65275.6	65157.6	51	58770.7	62878.9	52	62390.4	61852.7	54	56308.4	60400.2
51	63219.9	62947.8	54	56495.3	60587.1	55	60262.5	59557.6	57	54200.2	58272.3
49	64665.8	64551	52	59426.4	62036.3	53	61833	61292	55	57069.1	59655.9
53	61656	61383.8	56	56255.9	58836.3	57	58892	58177.3	59	53983.8	56541.2
55	59767.4	59492	58	57616.6	57039.5	59	57003.5	56272.3	61	55334.6	54734.6
48	62226.4	65265.8	51	58288.7	62787.1	52	59472.3	62075.6	54	55937.9	60416.6
46	66665.8	66977.3	49	60036.3	64547.8	50	64033	63931.4	52	57846.1	62341.2
51	57918.2	62862.5	54	61659.2	60446.1	55	54947.7	59416.6	58	57908.4	56665.8
54	57344.5	60377.3	57	58095.3	57951	58	54610	57167.4	60	55901.8	55734.6
53	58118.2	61157.6	56	59911.7	58682.2	57	55292	57859.2	59	57646.1	56400.2
56	59354.3	58560.9	59	57449.4	55996.9	60	56515	55259.2	62	55255.9	53780.5
50	59092	63639.6	53	58813.3	61416.6	54	56413.3	60501.9	56	56315	58892
55	54921.5	59472.3	58	57747.7	57177.2	59	52377.2	56433	61	55396.9	54800.2
54	55406.8	59957.6	57	58210	57492	58	52682.2	56737.9	60	55859.2	55121.5
49	64580.6	64465.8	52	59410	62016.6	53	61777.3	61239.6	55	57180.5	59767.4
55	56272.3	59311.7	58	57708.4	56987.1	59	53682.2	56239.5	61	55367.4	54623.1
52	62134.6	62016.6	55	59990.4	59285.5	56	59357.6	58800.2	58	57918.2	57196.9
47	61262.5	66206.8	50	61174	63790.4	51	58069.1	62567.4	54	57846.1	60433
46	66449.4	66757.6	49	60341.2	64462.5	50	63692	63587.1	52	57819.9	61921.5
54	55410	60354.3	57	59101.8	57869.1	58	52898.5	57351	60	56964.1	55714.9
48	64859.2	65164.2	51	59974	62583.8	52	62056	61937.9	54	57678.9	60265.8
57	55010	58036.3	60	56908.4	55655.9	61	52262.5	54790.4	63	54534.6	53265.8
55	60678.9	59885.5	58	57642.8	57492	59	57819.9	56577.2	61	55167.4	54993.6
43	66278.9	69328.1	46	62990.4	67128.1	47	63315	65954.3	52	57957.6	62059.2
52	57203.5	61751	55	59793.7	59229.7	56	54357.6	58429.7	58	57492	56908.4
54	55836.3	60387.1	57	58564.1	57846.1	59	52151	56203.5	61	55574	54833
54	57324.8	60367.4	57	58833	58265.8	58	54806.8	57374	60	56387.1	55796.9
53	57574	60616.6	56	59069.1	58357.6	57	55088.7	57662.5	59	56705.1	55974
52	62226.4	61951	55	59449.4	59315	56	59252.7	58541.2	58	57196.9	57042.8
52	58255.9	61292	55	54514.9	58980.5	56	55387.1	57954.3	58	52229.7	56675.6
51	62770.7	63078.9	54	56213.3	60695.3	55	59924.8	59793.7	57	53790.4	58252.7
57	52892	57833	60	56705.1	55452.7	61	50259.2	54685.4	63	54324.8	53052.6
51	62662.5	62964.2	54	57744.5	60334.6	55	59823.2	59688.7	57	55478.9	58046.1
51	63852.7	63059.2	54	58085.5	60675.6	55	60980.5	59760.9	57	55616.6	58183.8
52	61783.8	62092	55	60977.3	59757.6	56	59010	58875.6	58	57915	56672.3
47	62934.6	65980.6	50	59216.6	63528.1	51	59783.8	62396.9	53	56855.9	61151
53	55996.9	60544.5	56	59259.2	58698.6	57	53721.5	57787.1	59	56849.4	56269.1
46	67128.1	66856	49	60446.1	64567.4	50	64449.4	63774	52	57957.6	62059.2
57	54983.8	58023.2	60	56334.6	55747.7	61	52337.9	54878.9	63	53872.3	53259.2
54	56921.5	59967.4	57	58285.5	57567.4	58	53751	56311.7	60	56029.7	55295.3
55	59892	59619.9	58	57541.2	56964.1	59	56990.4	56259.2	61	55396.9	54796.9
48	62069.1	65115	51	58016.6	62508.4	52	59121.5	61724.8	54	55711.7	60187.1
48	60478.9	65419.9	51	63256	63147.8	52	57685.4	62177.3	57	57885.4	57737.9
56	53878.9	58823.2	59	57623.2	56377.2	60	50954.3	55387.1	62	55255.9	53990.4
55	56603.5	59633	58	57259.2	57108.4	59	53875.6	56419.9	61	54918.2	54744.5
57	54678.9	57705.1	60	56711.7	55459.2	61	52023.1	54547.7	63	54426.4	53154.3
55	59160.9	59459.2	58	58236.3	56993.6	59	56292	56124.8	61	55941.2	54682.2
50	60062.5	63108.4	53	56692	60783.8	54	57275.6	59869.1	56	54223.1	58292
53	56423.1	60974	56	60128.1	58698.6	57	53977.2	58046.1	59	57915	56469.1
52	62174	61898.6	55	55370.7	59846.1	56	59528.1	58819.9	58	52878.9	57331.4
48	62242.8	65288.8	51	63187.1	62659.2	52	58964.1	61567.4	57	57878.9	57308.4
47	66397	66124.8	50	61010.1	63626.5	51	63396.9	62715	53	57921.5	60515
52	62249.4	62131.4	55	60242.8	59537.9	56	59249.4	58688.7	58	57859.2	57137.9

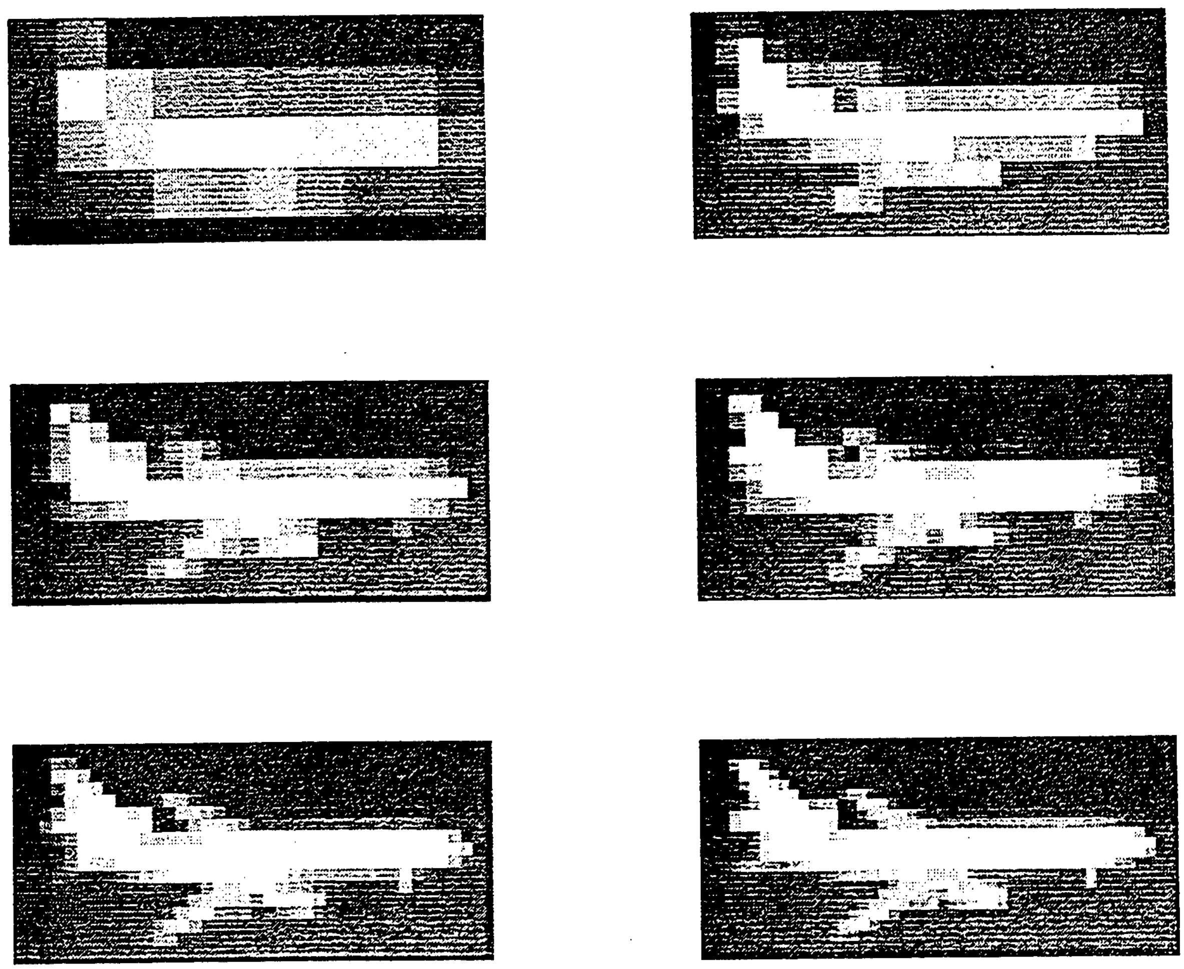
BASELINE-5	FINAL DATA														
	accuracy				first detection			first ID			first designation				
trial number	hits	miss	fa	cr	time	range	range to airfield	time	range	range to airfield	time	range	range to airfield		
average	1.82	0.08	0.18	3.93	9.78	94094	95736	43	66938	68460	46.63	64185	66161		
stdv	0.39	0.28	0.39	1.95	5.06	3267	4082	4	1760	2948	4.07	2279	3244		
39	2	0	0	6	10	91751.1	95544.6	42	65642.9	69324.8	47	60741.2	65685.5		
40	2	0	0	2	4	96597.1	100882	39	68141.2	72311.7	41	66151.1	71092.1		
41	1	1	1	7	6	94567.5	99046.2	40	67105.2	71469.1	45	63737.9	67987.1		
42	2	0	0	0	13	93059.3	93102	46	66419.9	66334.7	47	65783.8	66092		
43	2	1	0	5	17	89751.1	89711.8	48	64665.8	64508.4	55	60295.3	59501.9		
44	2	0	0	7	19	88951.1	88633.1	49	64278.9	63846.1	54	61233	60439.6		
45	2	0	0	4	9	93043	96239.7	43	66315	69383.9	47	63374	66147.8		
46	2	0	0	3	14	93472.5	92206.9	47	66603.5	65216.6	51	62403.5	62282.2		
47	1	0	1	7	7	94321.6	98128.2	40	67006.8	70695.3	46	62098.6	66344.5		
48	2	0	0	0	15	89033.1	91538	45	64295.3	66675.6	46	63780.6	66560.9		
49	2	0	0	5	15	92695.4	91892.1	48	66180.6	65262.5	51	62728.1	62967.4		
50	2	0	0	1	9	96452.8	96429.9	44	68036.3	67895.3	45	67167.5	67406.8		
87	2	0	0	2	3	96459.4	100941	38	68056	72423.2	41	65475.6	70416.6		
88	1	0	1	3	3	97495.4	101309	37	69564.2	73265.8	39	67970.7	72219.9		
89	2	0	0	3	16	90872.5	90583.9	48	65200.2	64793.7	51	63600.2	62806.8		
90	1	1	1	6	11	96190.5	95439.7	46	67875.6	67003.5	47	66793.7	66305.2		
91	2	0	0	2	11	95010.2	94213.4	46	67324.8	66413.4	48	65521.5	64728.1		
92	2	0	0	6	11	95170.8	94902	45	67370.7	66980.6	49	64692	63898.6		
93	2	0	0	1	3	97879	101856	38	69167.5	73039.6	39	68426.5	72675.7		
94	2	0	0	4	3	96541.3	101020	37	68997	73367.5	41	65515	69760.9		
95	2	0	0	0	8	97787.2	97777.4	44	68751.1	68619.9	45	67472.4	67715		
96	2	0	0	7	17	91193.8	89928.2	49	65357.6	63967.4	54	60610.1	60492		
97	2	0	0	6	16	91485.6	90675.7	48	65574	64649.4	51	62121.5	62364.2		
98	1	1	1	8	11	94803.6	94488.9	46	67164.2	66731.4	53	62092	61095.3		
135	2	0	0	5	8	93295.4	97095.4	41	66518.3	70203.5	45	62646.1	67590.4		
136	2	0	0	4	9	92308.5	96275.8	41	65908.4	69760.9	45	62229.7	67174		
137	1	0	1	4	3	96256.1	100538	39	67908.4	72075.7	40	66774	71324.8		
138	2	0	0	6	12	95098.7	93843	46	67308.4	65928.1	49	63675.6	63983.8		
139	2	0	0	3	21	84731.4	87006.9	49	62157.6	64301.9	52	59078.9	62111.7		
140	1	1	1	6	9	97164.3	95918.4	45	68298.6	66924.8	50	63196.9	63078.9		
141	2	0	0	3	3	99262.6	101597	40	69383.9	71580.6	44	65737.9	68515		
142	2	0	0	3	8	92452.8	96924.9	41	66019.9	70377.3	45	63351	67600.2		
143	2	0	0	2	10	97033.1	95974.1	45	68387.1	67213.4	47	65947.8	66193.7		
144	2	0	0	1	10	92741.3	95538	43	66249.4	68915	45	64259.2	67039.6		
145	2	0	0	4	11	92154.4	94669.2	44	65859.2	68242.9	45	65046.1	67819.9		
146	2	0	0	2	19	88334.7	88292.1	50	64026.5	63865.8	51	62885.5	63128.1		
165	2	0	0	4	18	86242.9	89006.9	48	62856	65485.5	49	61351	64387.1		
166	2	0	0	3	11	89783.9	94439.7	42	64721.5	69265.8	43	64088.8	69029.8		
167	2	0	0	4	6	93967.5	98636.4	40	66849.4	71403.5	41	65816.6	70757.6		
168	2	0	0	4	12	94705.2	93947.9	47	67242.9	66370.7	49	64446.1	64760.9		
169	2	0	0	6	11	92056.1	94577.4	44	65833	68223.2	48	61846.1	64892		
170	2	0	0	6	11	95390.5	95370.8	45	67567.5	67426.5	48	65934.7	65141.2		
171	2	0	0	4	4	98705.3	101036	40	69669.1	71869.1	43	66636.3	69413.4		
172	2	0	0	5	3	97098.7	101387	38	68419.9	72593.7	43	64865.8	69115		
173	2	0	0	4	3	96292.1	100968	39	68006.8	72570.8	49	60242.8	64492		
174	2	0	0	3	5	96629.9	99443	40	68082.2	70760.9	43	66206.8	68987.1		
175	2	0	0	4	13	90367.5	92669.2	45	64964.2	67134.7	48	61842.8	64619.9		
176	2	0	0	4	21	87446.2	86879	51	63600.2	62921.5	53	61006.8	61249.4		
207	2	0	0	7	4	96292.1	100269	40	67915	71780.6	44	63547.8	68488.8		
208	2	0	0	5	14	93164.3	92790.5	47	66351.1	65846.1	51	62390.4	62698.6		
210	2	0	0	4	12	93528.2	93502	46	66567.4	66426.5	51	63295.3	62501.9		
211	2	0	0	4	14	92947.9	92183.9	47	66229.7	65344.5	49	63508.4	63816.6		
212	1	0	1	3	6	95629.8	98836.4	40	67639.6	70718.3	43	65869.1	68915		
213	1	0	1	4	10	95764.3	95492.1	45	67688.8	67298.6	47	65351.1	65593.7		
214	2	0	0	2	4	98177.4	100505	41	68839.6	71033	46	64115	66892		
215	2	0	0	3	4	96262.6	100240	39	67931.4	71797	40	67301.9	71551.1		
216	2	0	0	7	7	98420	97885.6	44	69062.5	68416.6	49	64078.9	64324.8		
217	2	0	0	2	3	98265.9	101079	36	71072.4	73767.5	39	69069.1	71856		
218	1	0	1	4	10	95600.3	95328.2	45	67518.3	67131.4	46	66219.9	66213.4		
219	1	0	1	2	7	97469.2	97524.9	43	68537.9	68469.1	45	67475.6	67429.8		

BASELINE-5						FINAL DATA					
second designation			first lock			second lock			launch		
time	range	range to airfield	time	range	range to airfield	time	range	range to airfield	time	range	range to airfield
53.30	59113	60752	56.30	56818	58332	57.30	56354	57527	59.42	54378	55871
4.04	3879	3203	4.04	2533	3204	4.04	3868	3225	3.88	2308	3061
53	57862.5	60898.6	56	53816.6	58275.6	57	54980.5	57544.5	59	51524.8	55960.9
50	63570.7	63878.9	53	56839.5	61324.8	54	60708.4	60580.5	56	54537.9	59003.5
55	60498.6	59705.1	58	53721.5	57488.7	59	57859.2	56613.3	61	51246.1	54987.1
51	59855.9	62895.3	54	60469.1	60341.2	55	57019.9	59603.5	57	57905.1	57754.3
59	53282.2	56308.4	62	55131.3	53865.8	63	50269	52777.2	65	52665.8	51377.2
62	53462.5	53829.7	65	52623.1	51337.9	66	50764.1	50610	68	50357.6	49052.6
52	57751	62000.2	55	57403.5	59721.5	56	55085.4	58862.5	58	54977.2	57272.3
55	54931.3	59177.3	58	57193.6	56606.8	59	52114.9	55862.5	61	54888.7	54278.9
53	61118.2	60846.1	56	54737.9	58511.7	57	58246.1	57528.1	59	52305.1	56055.9
50	63272.4	63154.3	53	58482.2	60813.3	54	60633	60078.9	56	56174	58485.5
58	54508.4	57275.6	61	54829.7	54596.9	62	51354.3	53613.3	64	52662.5	52410
50	63518.3	63413.3	53	60983.8	60796.9	54	60475.6	59934.6	57	57951	57741.2
45	63803.5	66849.4	48	59937.9	64446.1	49	61259.2	63878.9	51	57862.5	62354.3
48	64534.7	64836.3	51	58639.6	62442.8	52	61846.1	61724.8	54	56282.2	60069.1
56	53718.2	58662.5	59	57511.7	56269.1	60	50983.8	55419.9	62	55121.5	53855.9
58	54321.5	57347.7	61	56016.6	55059.2	62	51633	54154.3	64	53551	52570.7
53	57698.6	60734.6	56	59541.2	58311.7	57	54777.2	57337.9	59	57078.9	55829.7
56	58203.5	58501.8	59	57337.9	56092	60	55410	55236.3	62	54987.1	53721.5
48	62692	65469.1	51	58937.9	62744.5	52	59915	62259.2	54	56819.9	60610.1
50	62872.4	62751	53	56816.6	60606.8	54	60069.1	59508.4	56	54390.4	58160.9
49	60190.4	64436.3	52	62252.7	62078.9	53	57508.4	61305.1	57	57862.5	57655.9
61	51918.2	54678.9	64	52823.1	52203.5	65	49367.4	51603.5	67	50596.9	49947.7
59	52980.5	55747.7	62	53662.5	53419.9	63	50429.7	52678.9	65	51321.5	51055.9
60	55085.4	55324.8	63	54433	52954.3	64	52449.4	52193.6	66	52131.3	50629.7
51	59482.2	62521.5	54	55675.6	60151	55	56836.3	59416.6	57	53492	57951
53	60367.4	60672.3	56	53695.3	58154.3	57	57439.5	57288.7	59	51514.9	55954.3
49	64915	64121.5	52	57554.3	61652.7	53	62105.1	60892	55	55177.2	59259.2
57	54587.1	57613.3	60	55246.1	55072.3	61	51813.3	54337.9	63	52947.7	52751
57	58862.5	58069.1	60	53098.5	55633	61	56137.9	54882.2	63	50918.2	53429.7
57	58295.3	57501.8	60	55452.7	54855.9	61	55246.1	53983.8	63	53213.3	52593.6
48	61167.4	65416.6	51	60485.5	62829.7	52	58036.3	61836.3	54	57908.4	60229.7
52	62160.9	62046.1	55	55855.9	59639.6	56	59410	58855.9	58	53442.8	57206.8
52	57757.6	62006.8	55	59898.6	59708.4	56	55177.2	58954.3	58	57531.4	57321.5
49	64049.4	63928.1	52	59331.4	61672.3	53	61357.6	60806.8	55	56895.3	59213.3
56	58633	58872.3	59	54193.6	56482.2	60	55721.5	55495.3	62	51954.3	54216.6
57	58272.3	58154.3	60	55915	55688.7	61	55554.3	54964.1	63	53596.9	53351
57	53213.3	58160.9	60	53190.4	55724.8	61	50439.5	54869	63	50875.6	53383.8
51	62256	62560.9	54	55787.1	60265.8	55	59524.8	59393.7	57	53367.4	57823.2
54	61128.1	60334.6	57	53393.6	57852.7	58	58252.7	57013.3	60	51098.5	55531.3
56	55970.7	58993.7	59	56587.1	56433	60	53275.6	55806.8	62	54396.9	54223.1
55	59826.4	59029.7	58	54337.9	56895.3	59	57285.4	56036.3	61	51928.1	54462.5
56	58442.8	58747.8	59	57796.9	56554.3	60	55751	55587.1	62	55367.4	54105.1
49	60344.5	64593.7	52	59751	62088.7	53	57685.4	61482.2	55	57531.4	59849.4
48	64918.3	64803.5	51	58708.4	62515	52	62311.7	61777.3	54	56370.7	60157.6
53	61023.2	61262.5	56	55121.5	58898.6	57	58236.3	58029.7	59	52701.8	56455.9
50	63298.6	63174	53	58616.6	60951	54	60433	59875.6	56	56183.8	58498.6
54	59524.8	59767.4	57	55144.5	57446.1	58	56911.7	56698.6	60	52855.9	55134.6
60	55672.3	55547.7	63	53593.6	53351	64	52977.2	52354.3	66	51154.3	50882.1
52	58859.2	61898.6	55	55095.3	59564.1	56	56141.2	58715	58	52806.7	57255.9
57	52924.8	57872.3	60	55541.2	55374	61	50341.2	54767.4	63	53308.4	53118.2
55	54252.7	59193.7	58	57803.5	56557.6	59	51465.8	55901.8	61	55714.9	54455.9
56	55029.7	58062.5	59	55934.6	55764.1	60	52351	54885.4	62	53518.2	53324.8
50	63134.6	63128.1	53	58082.2	60672.3	54	60134.6	59695.3	56	55737.9	58305.1
54	59606.8	59908.4	57	57705.1	57498.6	58	56921.5	56760.9	60	55410	55180.5
50	59354.3	63603.5	53	58931.4	61262.5	54	56646.1	60433	56	56639.5	58951
48	65275.6	65164.2	51	58754.3	62560.9	52	62472.4	61941.2	54	56521.5	60308.4
56	54472.3	58721.5	59	56354.3	56131.3	60	51741.2	55485.4	62	54092	53852.6
44	67888.8	67770.7	47	62996.9	65367.4	48	65170.7	64649.4	53	57878.9	60206.8
54	57062.5	59833	57	57849.4	57393.6	58	54377.2	56672.3	60	55587.1	55111.7
50	63069.1	63311.7	53	61429.7	60954.3	54	60377.3	60187.1	57	57852.7	57351

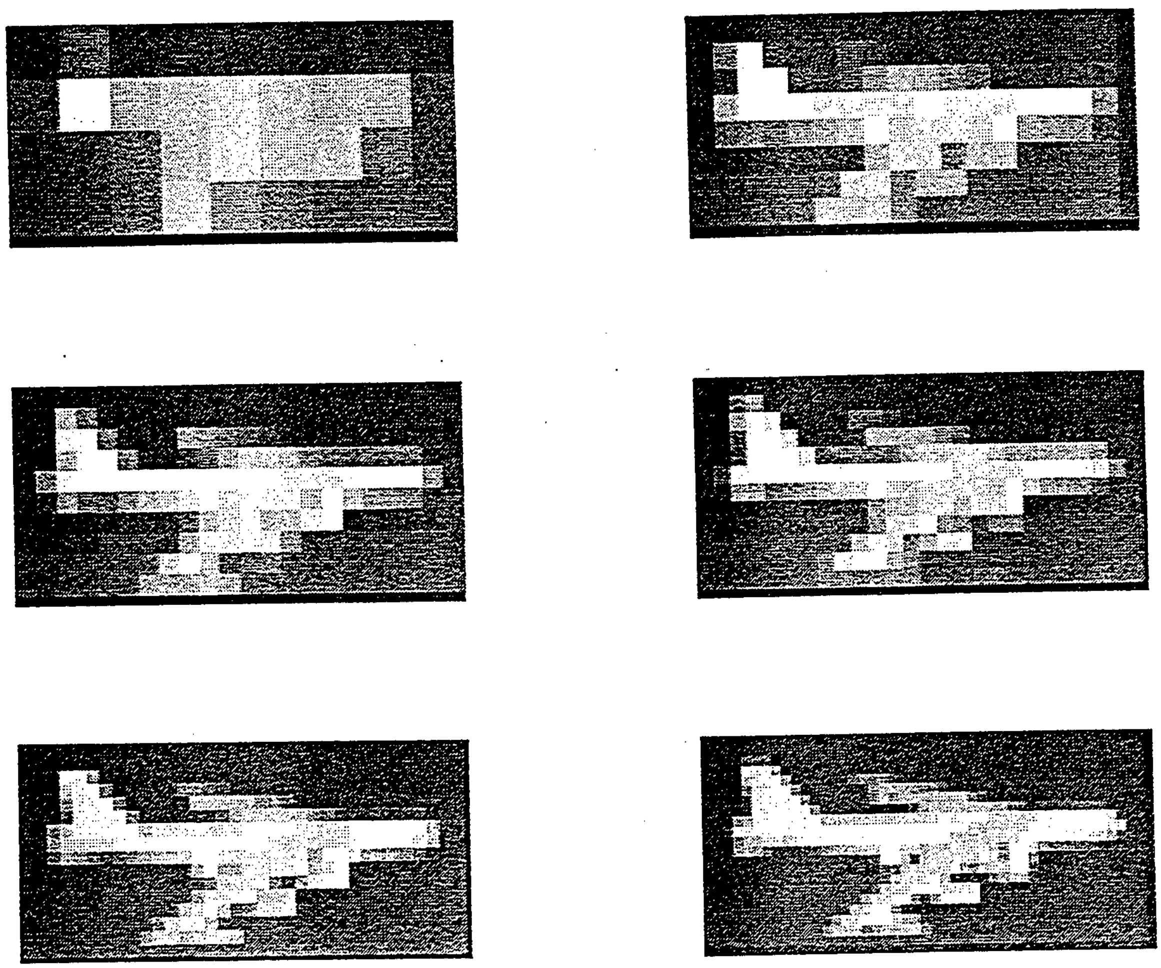
Appendix 1.2

Complete Set of Pixelated Views of KC-10 and B-52

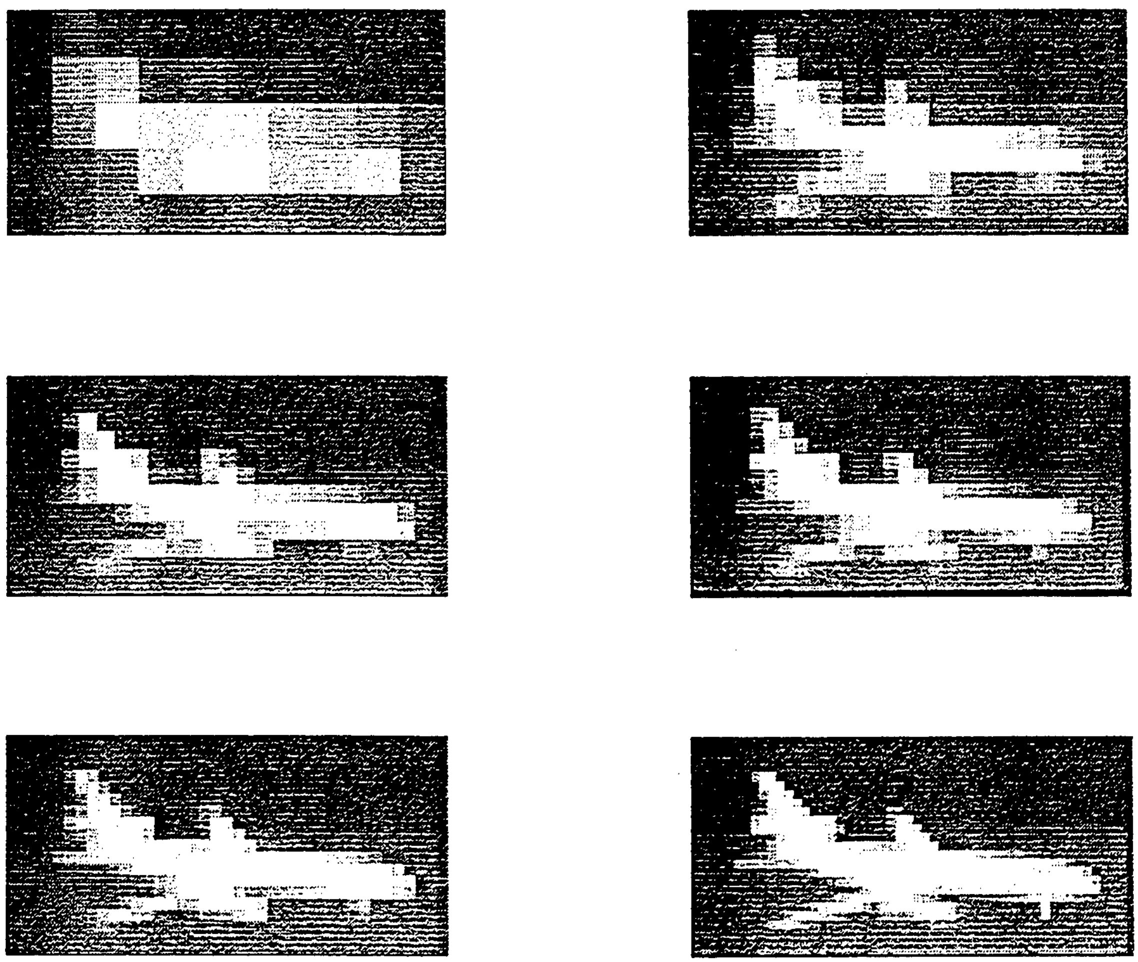
Different levels of pixelation of a KC-10 Model at an orientation of 0 degrees.



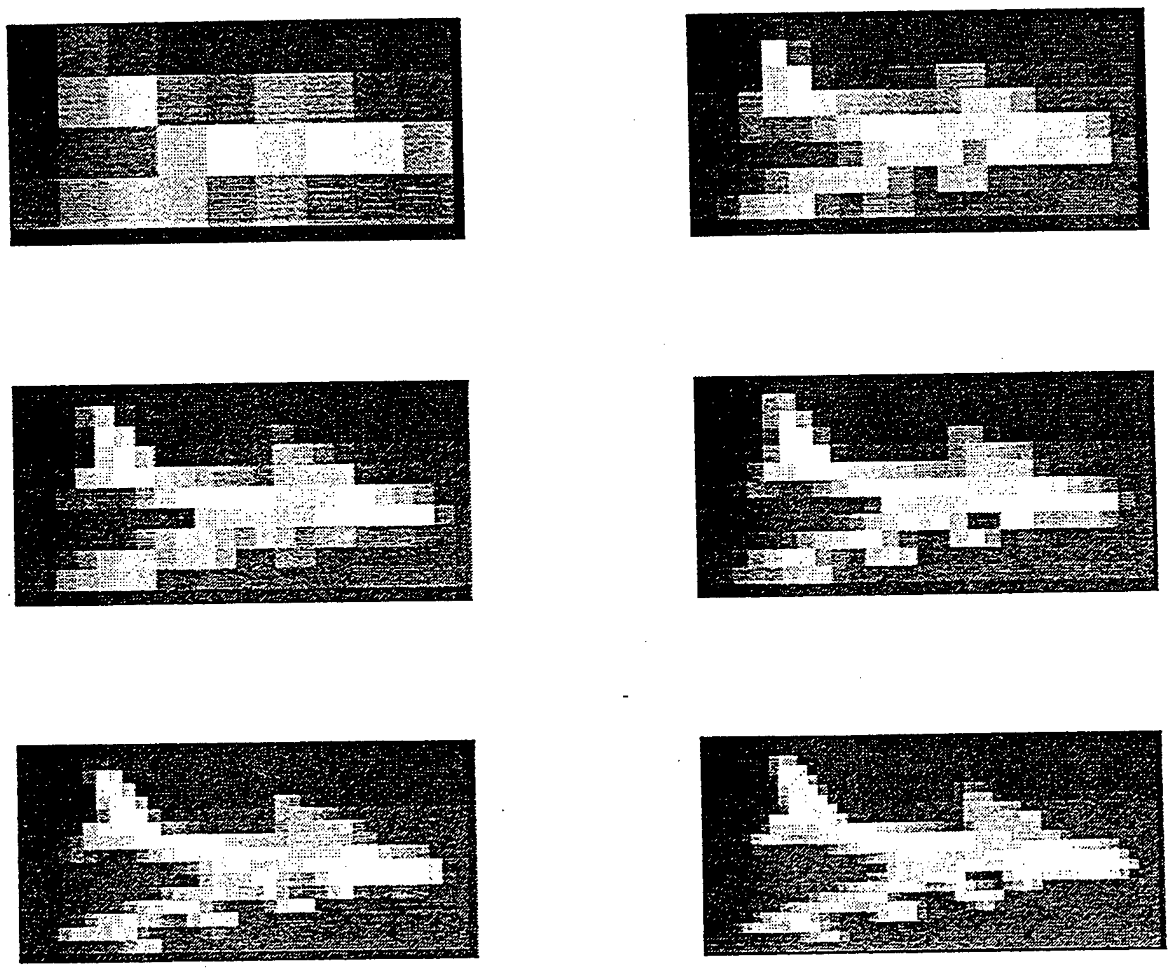
Different levels of pixelation of a B-52 Model at an orientation of 0 degrees.



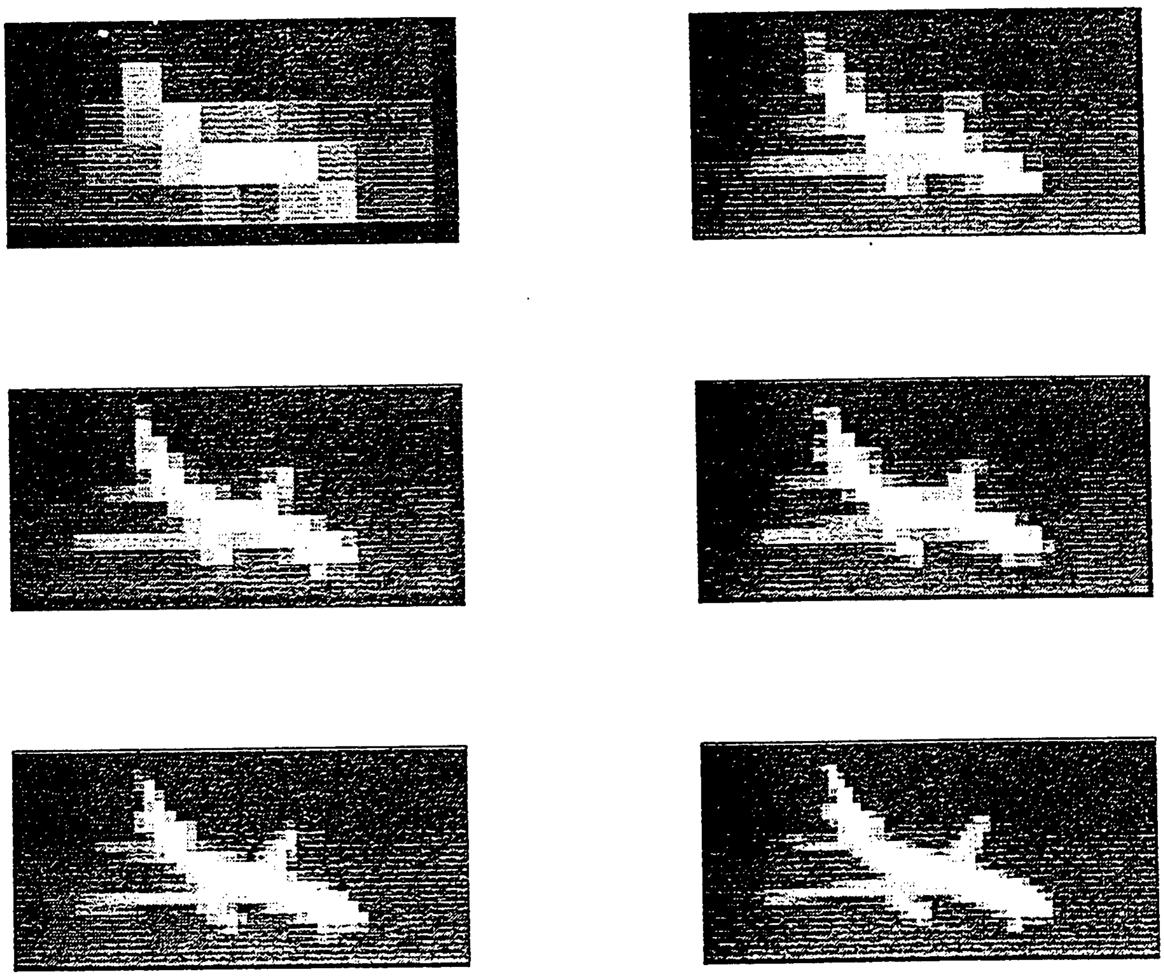
Different levels of pixelation of a KC-10 Model at an orientation of 30 degrees.



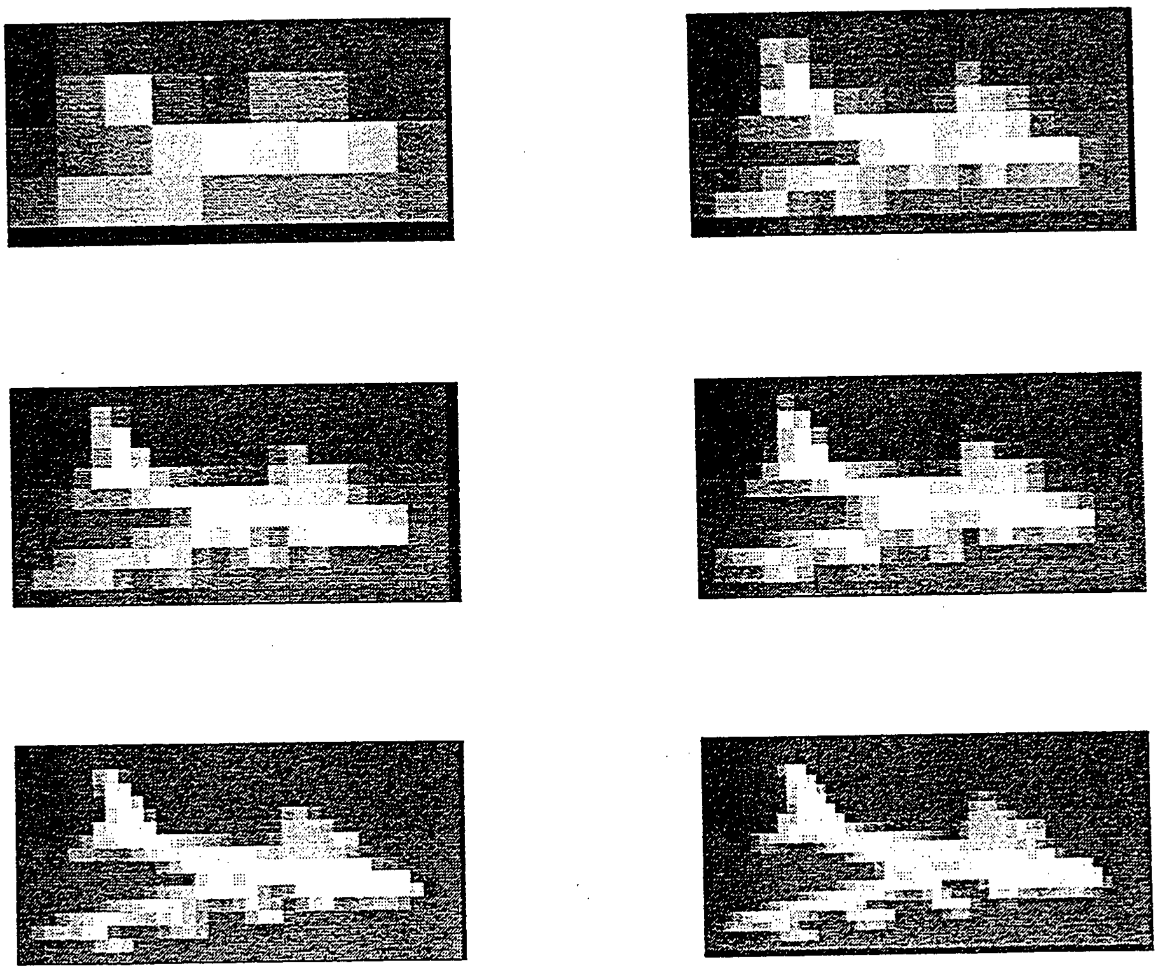
Different levels of pixelation of a B-52 Model at an orientation of 30 degrees.



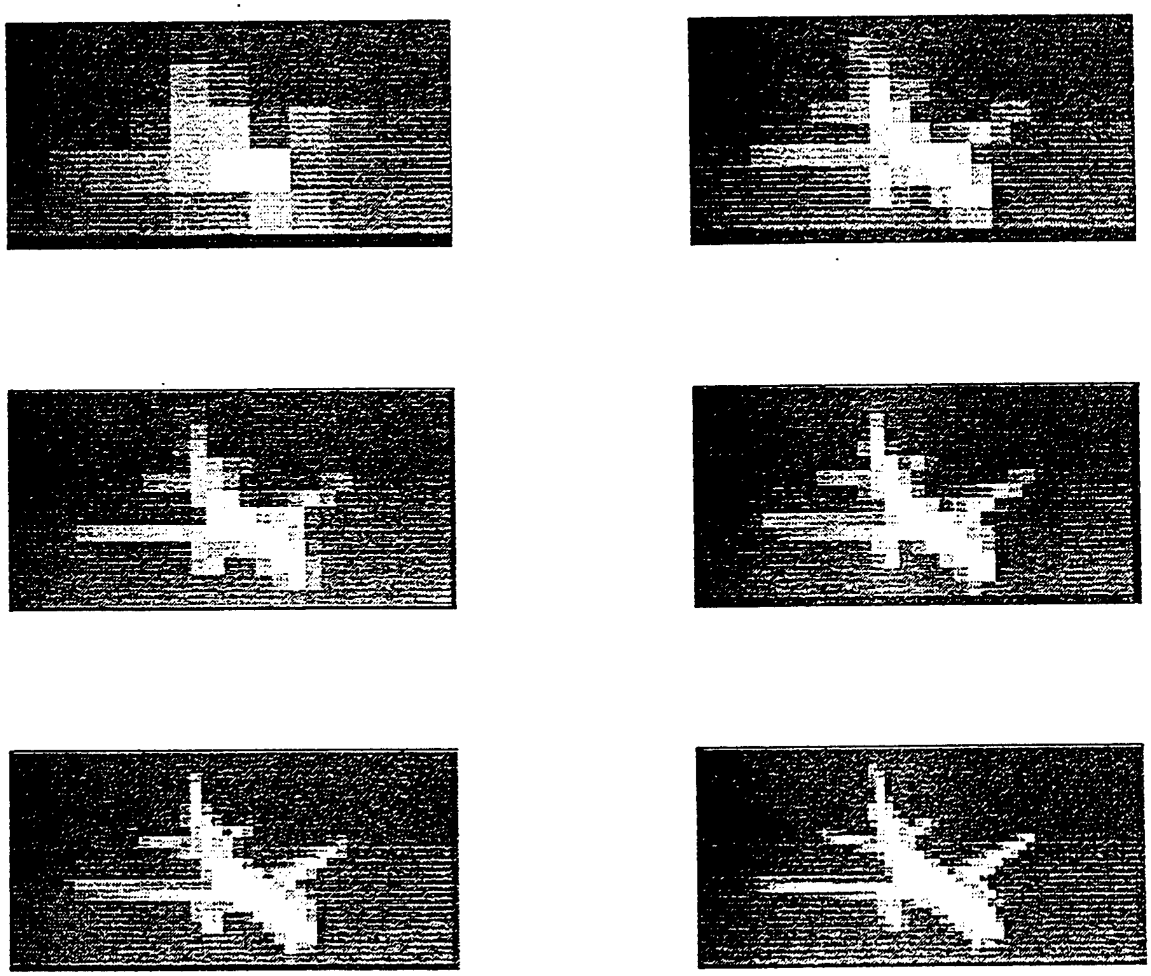
Different levels of pixelation of a KC-10 Model at an orientation of 45 degrees.



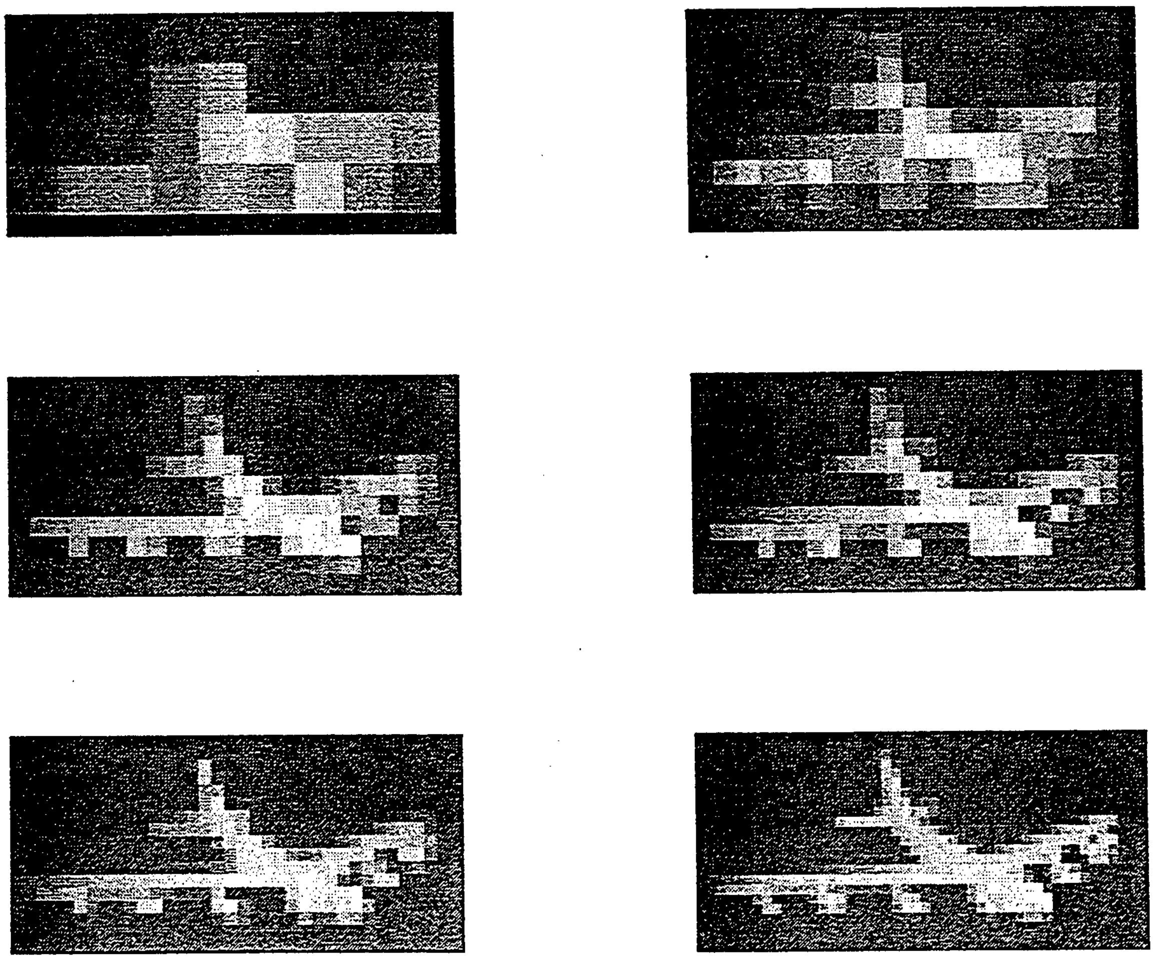
Different levels of pixelation of a B-52 Model at an orientation of 45 degrees.



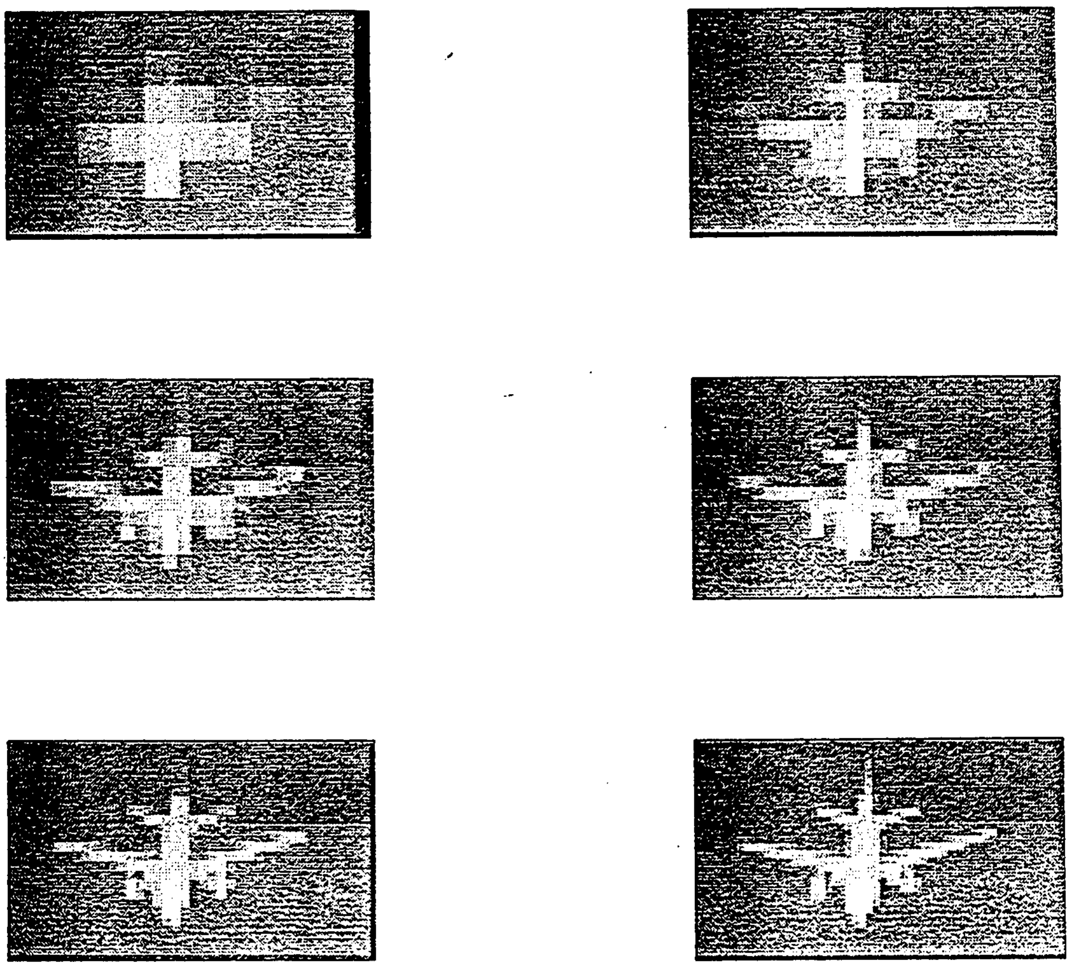
Different levels of pixelation of a KC-10 Model at an orientation of 60 degrees.



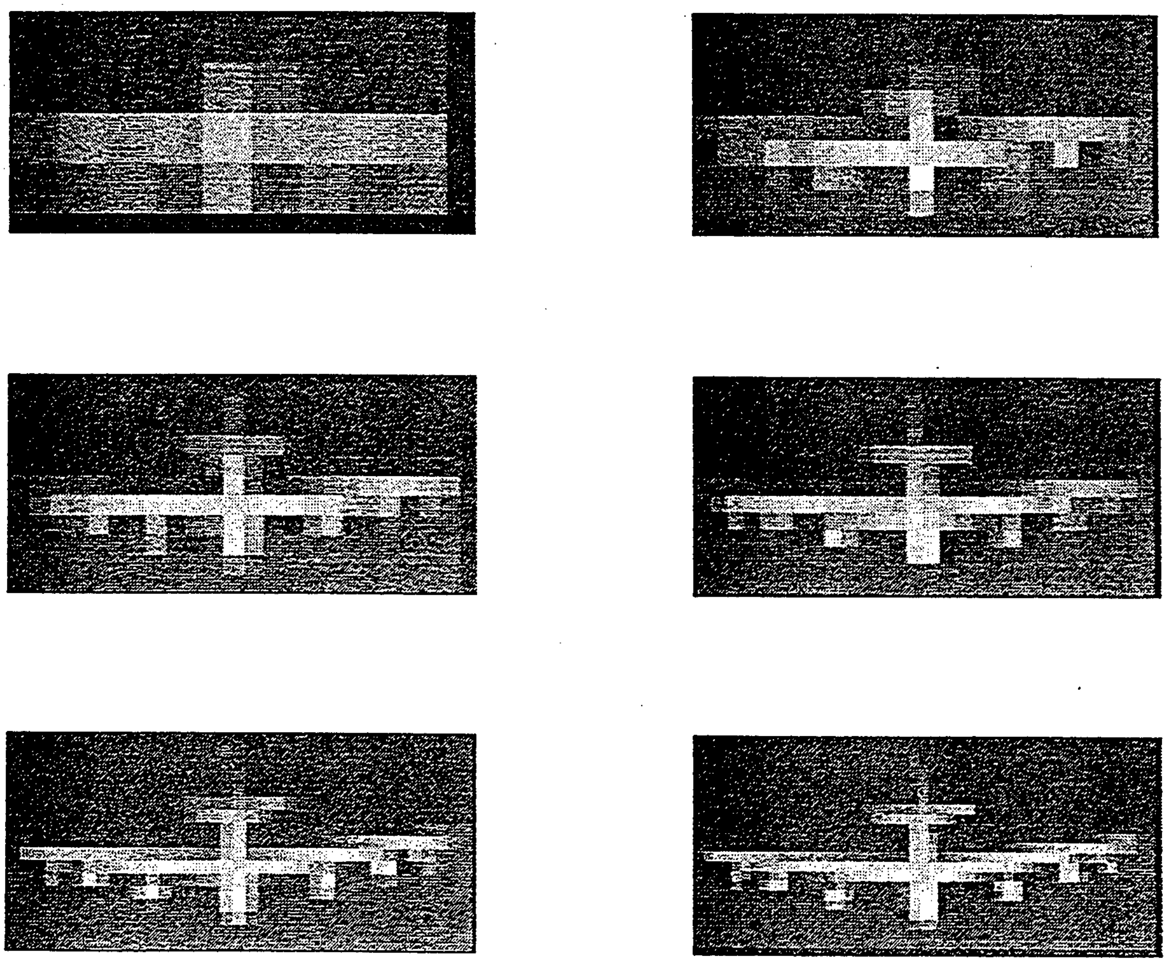
Different levels of pixelation of a B-52 Model at an orientation of 60 degrees.



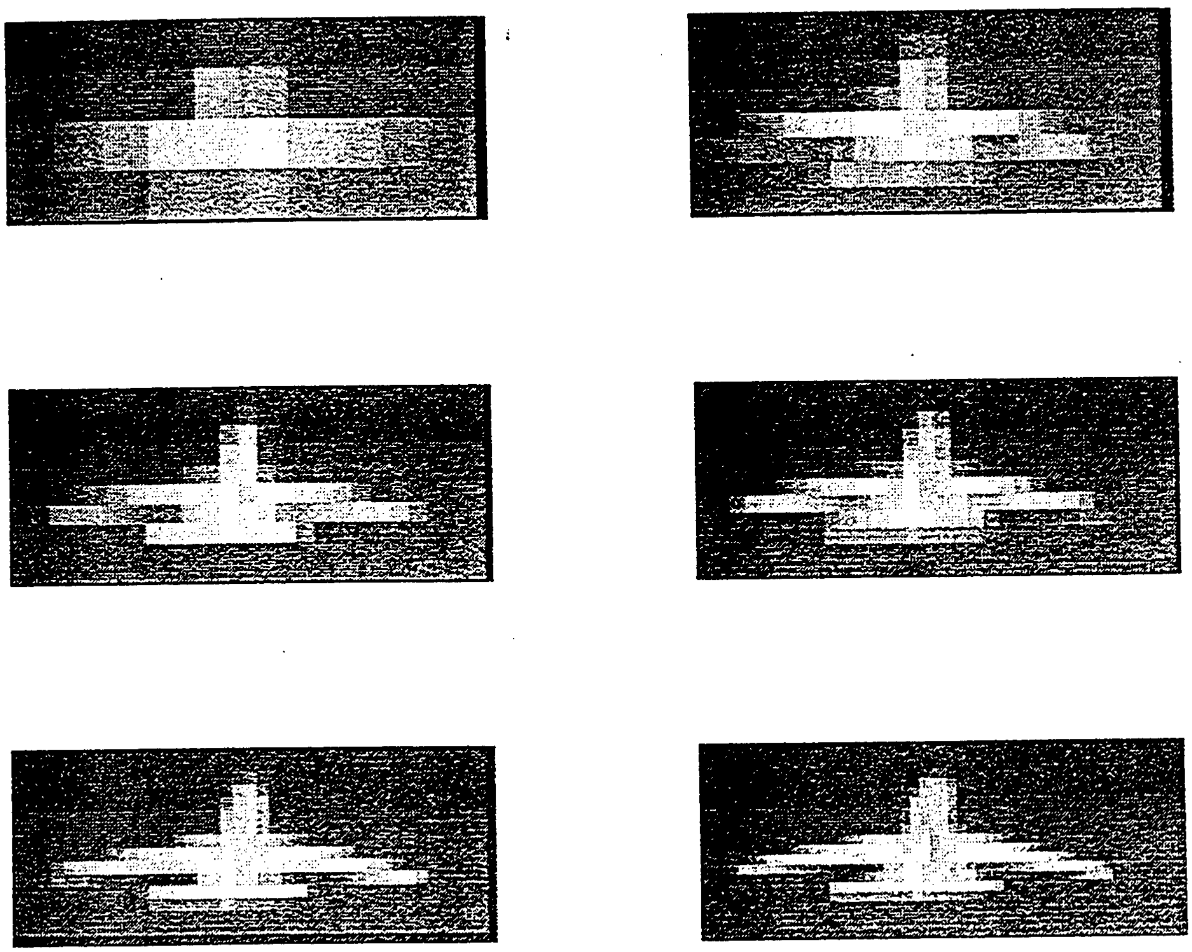
Different levels of pixelation of a KC-10 Model at an orientation of 90 degrees.



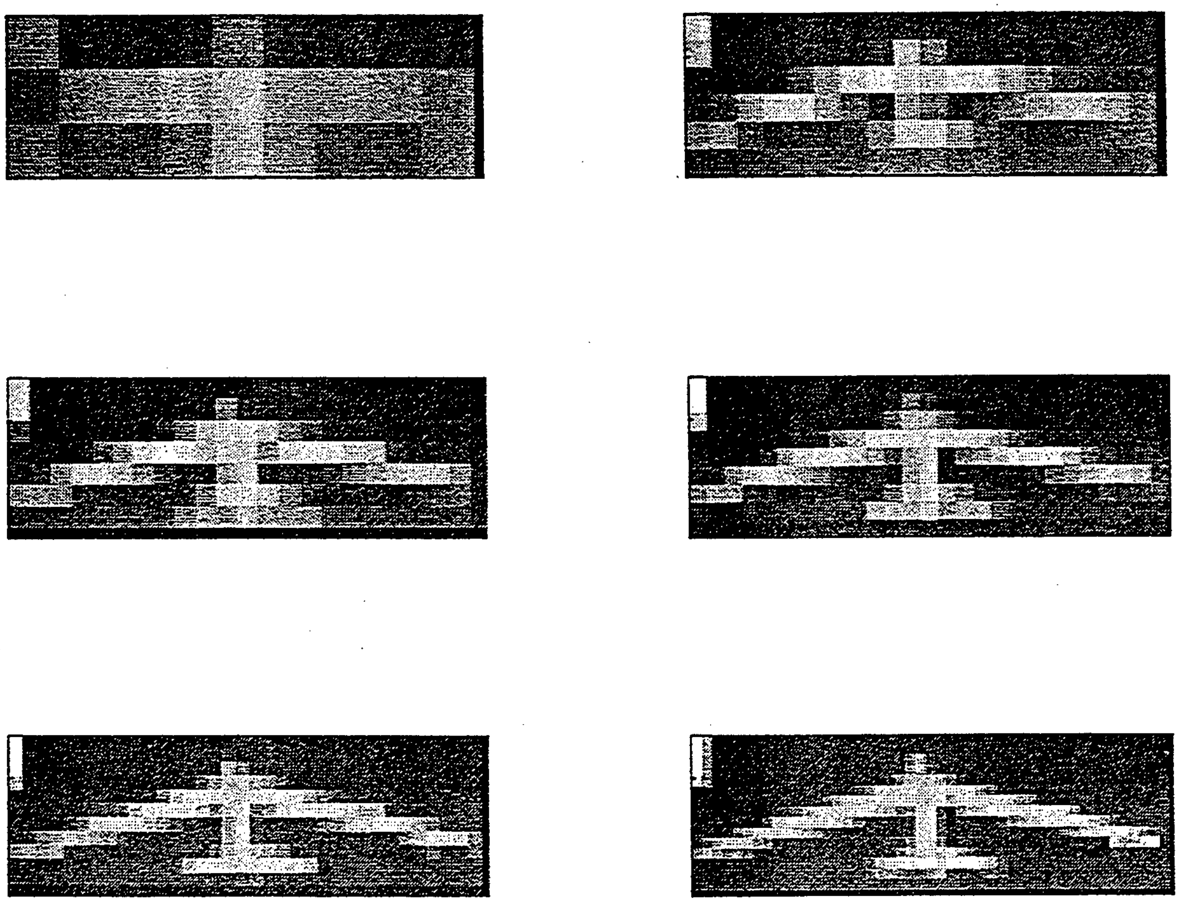
Different levels of pixelation of a B-52 Model at an orientation of 90 degrees.



Different levels of pixelation of a KC-10 Model at an orientation of -90 degrees.



Different levels of pixelation of a B-52 Model at an orientation of -90 degrees.



Appendix 1.3

Selected Text Output from the Baseline Condition

```
**** At waypoint: IP1. Type: initial. ****
Leaving Control Point
Leaving Control Point
 AT IP1 at time 12912
 Engage FLIR WFOV
**** Using Tactics: trail laydown level ****
**** Starting Route: attack ****
Desired Heading Type: waypoint-computer
 identified cluster two at time 12913
********slewing NFOV cursor at time 12913
Selected attack speed.
Selected speed: 247 m/s = 479 knots.
Route Altitude: 2286 meters = 7498 Feet.

 FLIR NFOV ENGAGED at time 12914
 done proposing selection of object to detect and identify at time 12914
 detected first plane: Z34 at range 97006.9 at time 12917

 identified  plane Z34 at range 68380.6 at time 12953
 ---CR--- 0.71 < 0.881467 at time 12953
 done proposing selection of object to detect and identify at time 12953
 detected plane: Z33 at range 67062.5 at time 12954
 identified  plane Z33 at range 67062.5 at time 12954
 ---CR--- 0.42 < 0.894867 at time 12954
 done proposing selection of object to detect and identify at time 12954

 detected plane: Z32 at range 67056. at time 12955
 identified  plane Z32 at range 67056. at time 12955
 ---CR--- 0.84 < 0.894933 at time 12955
 done proposing selection of object to detect and identify at time 12955
 detected plane: Z31 at range 66341.2 at time 12956
 identified  plane Z31 at range 66341.2 at time 12956
 ---CR--- 0.34 < 0.9022 at time 12956
 done proposing selection of object to detect and identify at time 12956

 detected plane: Z30 at range 65134.7 at time 12957
 identified  plane Z30 at range 65134.7 at time 12957
 ---HIT--  0.09 < 0.914467 at time 12957
 ---Designate--- at time 12957
 ---Designate Confirmed--- 1 at time 12958
 ---back to  WFOV ENGAGED --- at time 12958

 identified cluster one at time 12959
********slewing NFOV cursor at time 12959
 FLIR NFOV ENGAGED at time 12960
 done proposing selection of object to detect and identify at time 12960

 detected plane: Z27 at range 60764.1 at time 12961
 identified  plane Z27 at range 60764.1 at time 12961
 ---CR--- 0.7 < 0.9589 at time 12961
 done proposing selection of object to detect and identify at time 12961
 detected plane: Z26 at range 59315. at time 12962
 identified  plane Z26 at range 59315. at time 12962
 ---HIT--  0.2 < 0.973633 at time 12962

 ---Designate--- at time 12962
 ---Designate Confirmed--- 2 at time 12963
---switching to lock procedures-1-- at time  12963

--- locking maverick-1-- at time 12966

 ---Confirmed locked--- 1 at time 12966
---switching to lock procedures-2-- at time 12966
--- locking maverick-2-- at time 12967
 ---Confirmed locked--- 2 at time 12967

---switching to launch procedures--- at time 12967

--- push fire button at time 12969
--- write data to file--

Leaving Control Point
Leaving Control Point
**** Starting Route: egress ****
**** Fly to waypoint: one ****
```

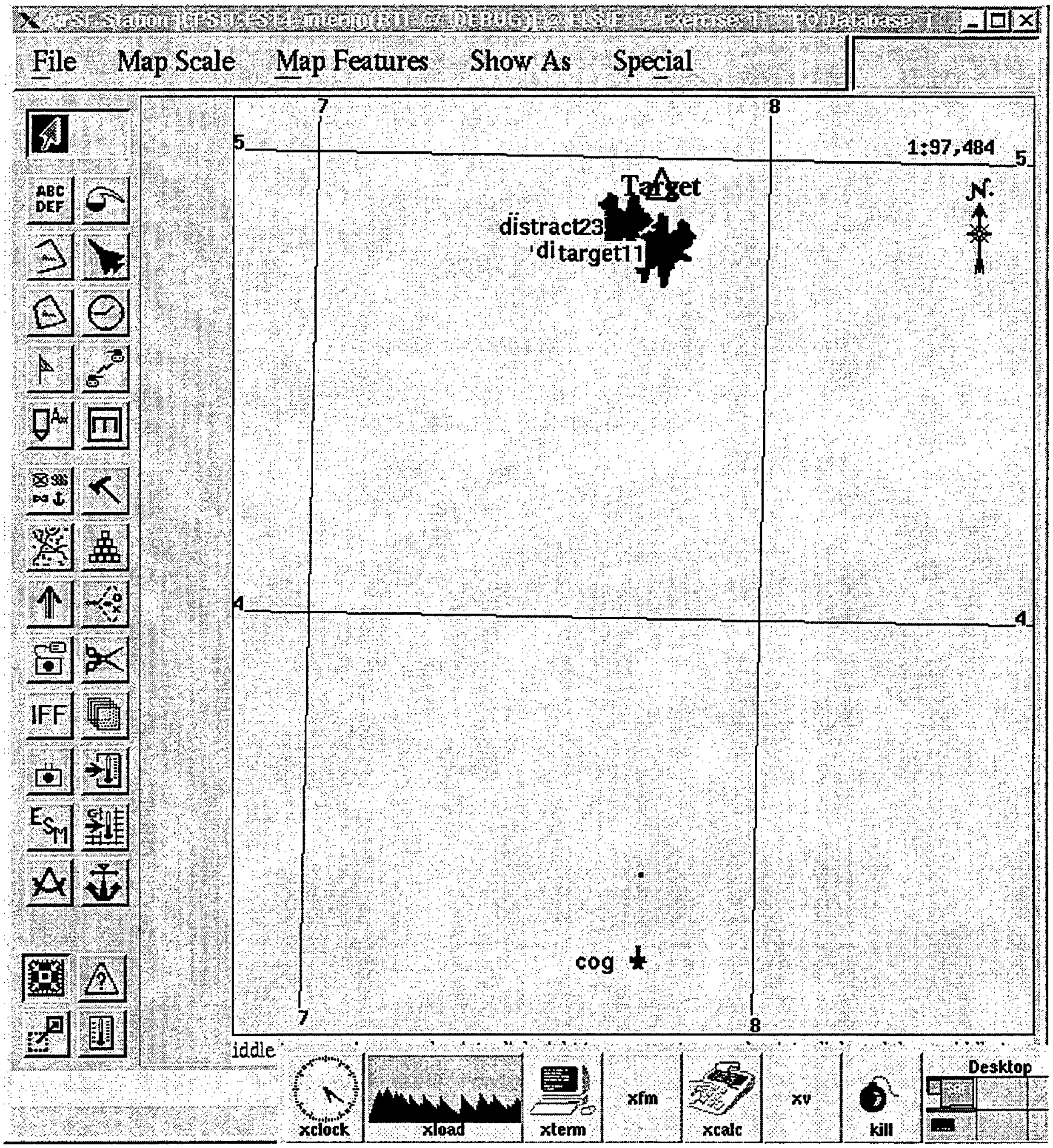
Appendix 1.4

Selected Text Output from the RTIC Condition

```
**** At waypoint: IP1. Type: initial. ****
Leaving Control Point
Leaving Control Point
 AT IP1 at time 13065
 Engage FLIR WFOV
**** Using Tactics: trail laydown level ****
**** Starting Route: attack ****
Desired Heading Type: waypoint-computer
Selected attack speed.
Selected speed: 247 m/s = 479 knots.
 identified cluster two at time 13066
********slewing NFOV cursor at time 13066

 FLIR NFOV ENGAGED at time 13067
 done proposing selection of object to detect and identify at time 13067
Route Altitude: 2286 meters = 7490 Feet.

 detected first plane: Z34 at range 95065.9 at time 13071
 ---CR--- at time 13071
 done proposing selection of object to detect and identify at time 13071
 detected plane: Z31 at range 95039.7 at time 13072
 ---CR--- at time 13072
 done proposing selection of object to detect and identify at time 13072
 detected plane: Z32 at range 94059.4 at time 13073
 ---CR--- at time 13073
 done proposing selection of object to detect and identify at time 13073

 detected plane: Z33 at range 94295.4 at time 13074
 ---HIT--- at time 13074
 ---Designate--- at time 13074
 ---Designate Confirmed--- 1 at time 13075
 ---back to  WFOV ENGAGED --- at time 13075

 identified cluster one at time 13076
********slewing NFOV cursor at time 13076
 FLIR NFOV ENGAGED at time 13077
 done proposing selection of object to detect and identify at time 13077

 detected plane: Z28 at range 89623.3 at time 13078
 ---CR--- at time 13078
 done proposing selection of object to detect and identify at time 13078
 detected plane: Z27 at range 88108.5 at time 13079
 ---HIT--- at time 13079

  ---Designate--- at time 13079
  ---Designate Confirmed--- 2 at time 13080
 ---switching to lock procedures-1-- at time  13080

 --- locking maverick-1-- at time 13083

  ---Confirmed locked--- 1 at time 13083
 ---switching to lock procedures-2-- at time 13083
 --- locking maverick-2-- at time 13084
  ---Confirmed locked--- 2 at time 13084
 ---switching to launch procedures--- at time 13084

 --- watching range icon--- at time 13086
 --- watching range icon--- at time 13087

 --- watching range icon--- at time 13088
 --- watching range icon--- at time 13089

 --- watching range icon--- at time 13090
 --- watching range icon--- at time 13091

--- watching range icon--- at time 13092
--- watching range icon--- at time 13093

--- watching range icon--- at time 13094
--- watching range icon--- at time 13095

--- watching range icon--- at time 13096
--- watching range icon--- at time 13097

--- watching range icon--- at time 13098
--- watching range icon--- at time 13099

--- watching range icon--- at time 13100
Warning: reached max-elaborations; proceeding to decision phase.
Warning: reached max-elaborations; proceeding to decision phase.

Warning: reached max-elaborations; proceeding to decision phase.
--- watching range icon--- at time 13101

--- watching range icon--- at time 13102
--- watching range icon--- at time 13103

--- watching range icon--- at time 13104
--- watching range icon--- at time 13105

--- watching range icon--- at time 13106
--- watching range icon--- at time 13107

--- watching range icon--- at time 13108
--- watching range icon--- at time 13109

--- watching range icon--- at time 13110
--- watching range icon--- at time 13111

--- watching range icon--- at time 13112
--- watching range icon--- at time 13113

--- watching range icon--- at time 13114
--- watching range icon--- at time 13115

--- watching range icon--- at time 13116
--- watching range icon--- at time 13117

--- watching range icon--- at time 13118
--- watching range icon--- at time 13119

Low or Medium Altitude.
--- push fire button at time 13119
--- write data to file--

Leaving Control Point
Leaving Control Point
**** Starting Route: egress ****
**** Fly to waypoint: one ****
```

Appendix 1.5

Snapshot Of A ModSAF Screen of a Plane Firing on Targets


File
Map Scale
Map Features
Show As
Special
1:97,484
Target
distract23
target11
cog
iddle
xclock
xload
xterm
xfm
xcalc
xv
kill
Desktop

Appendix 1.6

ANOVA Results

i

1 COCKPIT BREAKDOWN 1=ENHANCED, 2=BASELINE 13:28 Tuesday, October 21, 1997
1

--- CPIT=1 ---

Variable	Mean	Std Dev	N
FDT	13.3250000	4.8751858	120
FDR	91121.83	3457.02	120
SDT	19.4000000	4.6189234	120
SDR	86631.45	4405.17	120
SLT	23.4000000	4.6189234	120
SLR	83682.29	4388.57	120
LT	54.6083333	2.6735424	120
LR	57901.19	37.2018016	.120

--- CPIT=2 ---

Variable	Mean	Std Dev	N
FDT	46.5500000	3.9701618	120
FDR	64570.25	2142.86	120
SDT	52.5083333	3.7840795	120
SDR	59553.24	3813.64	120
SLT	56.5166667	3.7884906	120
SLR	56770.23	3782.00	120
LT	58.6750000	3.5930898	120
LR	55262.55	2135.15	120

1 TARGET COMPLEXITY BREAKDOWN 3= 3 TARGETS, 5= 5 TARGETS 13:28 Tuesday, October
21, 1997 2

TGT=3

Variable	Mean	Std Dev	N
FDT	29.6083333	17.4497097	120
FDR	78322.49	13682.87	120
SDT	34.9833333	17.2592605	120
SDR	73673.15	14306.77	120
SLT	38.9916667	17.2687583	120
SLR	70797.22	14230.96	120
LT	56.3583333	3.3224367	120
LR	57020.20	1378.07	120

TGT=5

Variable	Mean	Std Dev	N
FDT	30.2666667	17.0706556	120
FDR	77369.59	13576.42	120
SDT	36.9250000	16.9869760	120
SDR	72511.54	14081.22	120
SLT	40.9250000	16.9869760	120
SLR	69655.30	13984.20	120
LT	56.9250000	4.1468070	120
LR	56143.53	2405.03	120

-- CPIT=1 TGT=3 --

Variable	Mean	Std Dev	N
FDT	12.7500000	4.5682211	60
FDR	91689.83	3227.73	60
SDT	18.2500000	4.4707145	60
SDR	87352.33	4285.15	60
SLT	22.2500000	4.4707145	60
SLR	84407.62	4263.20	60
LT	54.7833333	2.7127550	60
LR	57893.54	36.0374301	60

-- CPIT=1 TGT=5 --

Variable	Mean	Std Dev	N
FDT	13.9000000	5.1377631	60
FDR	90553.82	3609.72	60
SDT	20.5500000	4.5114731	60
SDR	85910.58	4440.78	60
SLT	24.5500000	4.5114731	60
SLR	82956.96	4427.25	60
LT	54.4333333	2.6448970	60
LR	57908.83	37.0649392	60

-- CPIT=2 TGT=3 --

Variable	Mean	Std Dev	N
FDT	46.4666667	3.9033522	60
FDR	64955.15	1941.16	60
SDT	51.7166667	3.3652847	60
SDR	59993.98	3727.13	60
SLT	55.7333333	3.3792320	60
SLR	57186.82	3678.70	60
LT	57.9333333	3.1400457	60
LR	56146.87	1509.23	60

-- CPIT=2 TGT=5 --

Variable	Mean	Std Dev	N
FDT	46.6333333	4.0670927	60
FDR	64185.36	2278.62	60
SDT	53.3000000	4.0350162	60
SDR	59112.51	3879.14	60
SLT	57.3000000	4.0350162	60
SLR	56353.64	3868.30	60
LT	59.4166667	3.8808162	60
LR	54378.22	2307.97	60

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

Analysis of Variance Procedure

Dependent Variable: FDT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	66274.54583333	22091.51527778	1117.95	0.0001
Error	236	4663.51666667	19.76066384		
Corrected Total	239	70938.06250000			

R-Square	C.V.	Root MSE	FDT Mean
0.934259	14.84859	4.44529682	29.93750000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	66234.03750000	66234.03750000	3351.81	0.0001
TGT	1	26.00416667	26.00416667	1.32	0.2525
CPIT*TGT	1	14.50416667	14.50416667	0.73	0.3925

1 ANOVA FOR FIRST DESIGNATE RANGE 13:28 Tuesday, October 21, 1997 7

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

1 ANOVA FOR FIRST DESIGNATE RANGE 13:28 Tuesday, October 21, 1997 8

Analysis of Variance Procedure

Dependent Variable: FDR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	42355650185.17480000	14118550061.72490000	1742.57	0.0001
Error	236	1912103203.95605000	8102132.22015278		
Corrected Total	239	44267753389.13080000			

R-Square	C.V.	Root MSE	FDR Mean
0.956806	3.656479	2846.42446240	77846.03916667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	42299157478.20650000	42299157478.20650000	5220.74	0.0001
TGT	1	54480914.01879880	54480914.01879880	6.72	0.0101
CPIT*TGT	1	2011792.94946289	2011792.94946289	0.25	0.6187

1 ANOVA FOR SECOND DESIGNATE TIME 13:28 Tuesday, October 21, 1997 9

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

1 ANOVA FOR SECOND DESIGNATE TIME 13:28 Tuesday, October 21, 1997 10

Analysis of Variance Procedure

Dependent Variable: SDT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	66003.61250000	22001.20416667	1295.19	0.0001
Error	236	4008.88333333	16.98679379		
Corrected Total	239	70012.49583333			

R-Square	C.V.	Root MSE	SDT Mean
0.942740	11.46322	4.12150383	35.95416667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	65769.70416667	65769.70416667	3871.81	0.0001
TGT	1	226.20416667	226.20416667	13.32	0.0003
CPIT*TGT	1	7.70416667	7.70416667	0.45	0.5013

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

Analysis of Variance Procedure

Dependent Variable: SDR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	44079436380.94600000	14693145460.31530000	876.91	0.0001
Error	236	3954306993.26879000	16755538.10707110		
Corrected Total	239	48033743374.21480000			

R-Square	C.V.	Root MSE	SDR Mean
0.917676	5.600248	4093.35291748	73092.34666667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	43993767408.24410000	43993767408.24410000	2625.63	0.0001
TGT	1	80960267.52465820	80960267.52465820	4.83	0.0289
CPIT*TGT	1	4708705.17724609	4708705.17724609	0.28	0.5965

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

Analysis of Variance Procedure

Dependent Variable: FLT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	66003.61250000	22001.20416667	1295.19	0.0001
Error	236	4008.88333333	16.98679379		
Corrected Total	239	70012.49583333			

R-Square	C.V.	Root MSE	FLT Mean
0.942740	10.58039	4.12150383	38.95416667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	65769.70416667	65769.70416667	3871.81	0.0001
TGT	1	226.20416667	226.20416667	13.32	0.0003
CPIT*TGT	1	7.70416667	7.70416667	0.45	0.5013

1 ANOVA FOR FIRST LOCK RANGE 15:10 Tuesday, October 21, 1997 6

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

1 ANOVA FOR FIRST LOCK RANGE 15:10 Tuesday, October 21, 1997 7

Analysis of Variance Procedure

Dependent Variable: FLR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	41792862254.16520000	13930954084.72170000	1695.58	0.0001
Error	236	1938987021.95532000	8216046.70320052		
Corrected Total	239	43731849276.12060000			

R-Square	C.V.	Root MSE	FLR Mean
0.955662	4.041129	2866.36471915	70929.79750000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	41556448362.24240000	41556448362.24240000	5057.96	0.0001
TGT	1	236063475.65600500	236063475.65600500	28.73	0.0001
CPIT*TGT	1	350416.26684570	350416.26684570	0.04	0.8366

1 ANOVA FOR SECOND LOCK TIME 13:28 Tuesday, October 21, 1997 13

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

1 ANOVA FOR SECOND LOCK TIME 13:28 Tuesday, October 21, 1997 14

Analysis of Variance Procedure

Dependent Variable: SLT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	66035.15000000	22011.71666667	1294.02	0.0001
Error	236	4014.43333333	17.01031073		
Corrected Total	239	70049.58333333			

R-Square	C.V.	Root MSE	SLT Mean
0.942692	10.32164	4.12435580	39.95833333

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	65802.81666667	65802.81666667	3868.41	0.0001
TGT	1	224.26666667	224.26666667	13.18	0.0003
CPIT*TGT	1	8.06666667	8.06666667	0.47	0.4917

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

Analysis of Variance Procedure

Dependent Variable: SLR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	43539490896.26140000	14513163632.08710000	875.98	0.0001
Error	236	3910048834.88891000	16568003.53766490		
Corrected Total	239	47449539731.15030000			

R-Square	C.V.	Root MSE	SLR Mean
0.917596	5.796096	4070.38125213	70226.25666667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	43455533024.20500000	43455533024.20500000	2622.86	0.0001
TGT	1	78238648.80126950	78238648.80126950	4.72	0.0308
CPIT*TGT	1	5719223.25512695	5719223.25512695	0.35	0.5574

1 ANOVA FOR LAUNCH TIME 13:28 Tuesday, October 21, 1997 17

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

1 ANOVA FOR LAUNCH TIME 13:28 Tuesday, October 21, 1997 18

Analysis of Variance Procedure

Dependent Variable: LT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1061.95000000	353.98333333	36.05	0.0001
Error	236	2317.23333333	9.81878531		
Corrected Total	239	3379.18333333			

R-Square	C.V.	Root MSE	LT Mean
0.314262	5.532136	3.13349411	56.64166667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	992.26666667	992.26666667	101.06	0.0001
TGT	1	19.26666667	19.26666667	1.96	0.1626
CPIT*TGT	1	50.41666667	50.41666667	5.13	0.0244

1 ANOVAS FOR LAUNCH RANGE 13:28 Tuesday, October 21, 1997 19

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
CPIT	2	1 2
TGT	2	3 5

Number of observations in data set = 240

1 ANOVAS FOR LAUNCH RANGE 13:28 Tuesday, October 21, 1997 20

Analysis of Variance Procedure

Dependent Variable: LR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	511595693.10827600	170531897.70275800	89.67	0.0001
Error	236	448822124.32788000	1901788.66240628		
Corrected Total	239	960417817.43615700			

R-Square	C.V.	Root MSE	LR Mean
0.532680	2.437271	1379.05353863	56581.86625000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
CPIT	1	417746054.56872500	417746054.56872500	219.66	0.0001
TGT	1	46113455.67102050	46113455.67102050	24.25	0.0001
CPIT*TGT	1	47736182.86853020	47736182.86853020	25.10	0.0001

Appendix 1.7

Soar Source Code

```
echo "sytronics/cognitive-model.soar "
### -*- Mode: SDE -*-
###########################################################################
###
### File                 : cg1.soar
### Original author(s)   : David Darkow, William Marshak
### Organization         : Sytronics
### Created on           : 14 may 1997
### Last Modified By     : DD <ddarkow@sytronics.com>
### Last Modified On     : 7 August 1997, 17:02:07
### Soar Version         : 7
###
### Description :          criterion is 90%
###                        At Ipl start timer
###                        engage pseudo WFOV (visibility from.rdr)
###                        Identify clusters
###                        Identify airfield
###                        Select group to focus on
###                        Slew pseudo NFOV to first group
###                        Detect discrete targets in group 1
###                           if RTIC detect all targets in group
###                           if RTIC when all of group detected pick 1
###                           if baseline Identify discrete targets
###                             in group until ID target, fa or all
###                        Designate target 1
###                        Confirm target 1
###                        back to pseudo WFOV
###                        Slew pseudo NFOV to other group
###                        Dectect discrete targets in group 2
###                        Target second kc-10
###                        Designate target 2
###                        Confirm target 2
###                        Lock Maverick 1
###                        Lock Maverick 2
###                        Watch range symbol
###                        Launch
###                        Print results
###                        Return to base
###
###########################################################################
#####################################################################

#################################################################
# after vision of plane on input link choose
#     (1) detection range
#     (2) identification range
#################################################################
sp {cm*calculate*range-precursors
   (state <s> ^operator <o>
              ^top-state <ts>
              ^top-state.current-time.value <ct>
              ^top-state.vision.object <pl1>

    )
       (<o> ^name wait )
      (<pl1> -^id-range1
       )

-->
( <pl1> ^id-range1   (/ (mod (abs (int (* (sin <ct>) 1000000) ) ) 100 ) 1 ) )
( <pl1> ^id-range2   (/ (mod (abs (int (* (sin <ct>) 10000) ) ) 100 ) 1 ) )
( <pl1> ^id-range3   (/ (mod (abs (int (* (sin <ct>) 100) ) ) 100 ) 1 ) )
( <pl1> ^detect-range1   (/ (mod (abs (int (* (sin <ct>) 1000000) ) ) 100 ) 1
 ) )
( <pl1> ^detect-range2   (/ (mod (abs (int (* (sin <ct>) 10000) ) ) 100 ) 1 )
 )
( <pl1> ^detect-range3   (/ (mod (abs (int (* (sin <ct>) 100) ) ) 100 ) 1 ) )
}
#################################################################
# for every plane soon decide on detect and
#   identification range
# detect 23,000 +/- 3000 (stdev?)
# id     13,000 +/- 2000 (stdev?)
#################################################################
sp {cm*calculate*id-detect-ranges
   (state <s> ^operator <o>
              ^top-state <ts>
              ^top-state.current-time.value <ct>
              ^top-state.vision.object <pl1>
              ^top-state.cog-model.detect-mean <dm>
              ^top-state.cog-model.detect-stdev <ds>
              ^top-state.cog-model.id-mean <im>
              ^top-state.cog-model.id-stdev <is>
              ^top-state.cog-model.id-heading-decrease <dhd3>

    )
       (<o> ^name wait )
      (<pl1> -^id-range
              ^id-range1 <i1>
              ^id-range2 <i2>
              ^id-range3 <i3>
              ^detect-range1 <d1>
              ^detect-range2 <d2>
              ^detect-range3 <d3>
              ^heading.value <ahd3>
       )
-->
( <pl1> ^id-range (+ (* (- (/ (+ <i1> (+ <i2> <i3> ) ) 300 ) 0.5 ) <is> ) (-
 <im> (* <dhd3> (abs (cos <ahd3>))) ) ) )
( <pl1> ^detect-range  (+ (* (- (/ (+ <d1> (+ <d2> <d3> ) ) 300 ) 0.5 ) <ds>
 ) <dm> ) )
}

#################################################################
#####################################################################
#####################################################################
# Read file named "trialnum" to determine trial number
#  so can output number to output file named "cogdata"
#####################################################################
sp {cm*cognitive-model*data-collection*open-trial
    (state <s> ^top-state <ts>
               ^operator <o>

      )
     (<o> ^name init-agent
       )
    (<ts> -^cog-model
           ^current-time.value <ct>
      )

 -->
 (<ts> ^cog-model <cg> )
 (<cg> ^trial-file trialnum
       ^data <d3>
       ^pilot-tasks <pt3>
       ^detect-mean 28500
       ^detect-stdev 2000
       ^id-mean 20300  #66,000 feet = 25 pixels
       ^id-stdev 1000
       ^id-heading-decrease 0
       ^max-mav-range 17678
       ^min-mav-range 1524
       ^m (/ -0.2 (* 4 500 ) )
       ^b (- 1  (* (- 20300 (* 2 500)) (/ -0.2 (* 4 500 ) ) ) )
   }
```

```
( <pt3> ^speed-time (+ <ct> 1 )
        ^altitude-time (+ <ct> 1 )
        ^heading-time (+ <ct> 1 )
 )
(<d3> ^hit-count 0
      ^miss-count 0
      ^fa-count 0
      ^cr-count 0
)
(write (crlf) |got updated| )
(tcl |set fileid [open trialnum r]| )
(tcl |set a [gets $fileid]| )
(tcl |incr a|)
(tcl |close $fileid|)
(tcl |set fileid [open trialnum w]| )
(tcl |puts $fileid $a|)
(tcl |close $fileid|)
(<cg> ^trialnum1 (tcl |expr $a*1|) )
)

####################################################
########################################################
######################################################################
##################################################
#  initalize parameters and start clock when at IP1
#  criterion is 90%
########################################################################
sp {cm*note-start-attack-timer*apply*normal
   (state <s> ^operator <o> ^top-state <ts>)
         (<o> ^name fly-control-route
              ^route.from.name |IP1|  )
        (<ts> ^current-time.value <ct>
              ^parameter <p1>
              ^cog-model.data <cd8>
         )
        (<p1> -^criteria
              -^found-field
              -airfield-range
        )
 -->
     (<ts> ^group <gr1>
           ^airfield-range 20000.0
     )
     (<cd8> ^behavior rtic    # baseline
            ^ident-time 0
            ^ident-range 0
            ^ident-rrange 0
     )
     (<gr1> ^one <one>
            ^two <two>
            ^three <three>
            ^four <four>
            ^number 5
            ^cluster-count 0
      )
     (<one> ^lat1 82100
            ^lat2 82500
           ^long1 48000
           ^long2 48400
            ^count 0
            ^count-id 0
            ^sum-x 0
            ^sum-y 0
            ^rtic <rtic1>
      )
     (<rtic1> ^r1 165
            ^r2 185
            ^a1 -1.0
            ^a2 -0.8
)
(<two> ^lat1 81300
       ^lat2 81700
       ^long1 48500
       ^long2 48900
        ^count 0
        ^count-id 0
        ^sum-x 0
        ^sum-y 0
        ^rtic <rtic2>
  )
 (<rtic2> ^r1 80
          ^r2 100
          ^a1 0.65
          ^a2 0.85
 )
(<three> ^lat1 82900
         ^lat2 83400
         ^long1 49400
         ^long2 49900
         ^count 0
         ^count-id 0
         ^sum-x 0
         ^sum-y 0
         ^rtic <rtic3>
  )
 (<rtic3> ^r1 180
          ^r2 200
          ^a1 -1.3
          ^a2 -1.1
 )
 (<four> ^lat1 81500
         ^lat2 82400
        ^long1 49300
        ^long2 49900
        ^count 0
        ^count-id 0
        ^sum-x 0
        ^sum-y 0
        ^rtic <rtic4>
 )
 (<rtic4> ^r1 254
          ^r2 274
          ^a1 0.5
          ^a2 0.7
  )
  (<p1> ^zzzstartattacktime <ct> +
        ^criteria .900
        ^designate-count 0
        ^hit-count 0
        ^lock-count 0
        ^found-field 0
        ^rtic *yes*
#        ^baseline *yes*
    )
 (write (crlf) | AT IP1 at time | <ct> )
 (write (crlf) | Engage FLIR WFOV |  )
}

#####################################################################
# Identify airfield by detecting all planes in scenario
#####################################################################
#propose count a plane on the airfield
```

```
##########################################################################
sp (cm*count*propose*no-active-group
    (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
    (<ts> ^current-time.value <ct>
          ^vision.object <vl>
          ^parameter.zzzstartattacktime <ps>
          ^airfield-range <arl>
          -^group.active
       )
    (<vl> ^airborne *no*
          -^counted
       )
-->
(<s> ^operator <o> +, = )
(<o> ^name count-plane
     ^object <vl>
  )
(write (crlf) |propose count one more in group| )
)

##########################################################################
#propose count a plane in the group
##########################################################################
sp (cm*count*propose*active-group-exists
    (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
    (<ts> ^current-time.value <ct>
          ^vision.object <vl>
          ^parameter.zzzstartattacktime <ps>
          ^airfield-range <arl>
                ^group.<act1>.lat1 <x1>
                ^group.<act1>.lat2 <x2>
                ^group.<act1>.long1 <y1>
                ^group.<act1>.long2 <y2>
                ^group.active <act1>
       )
    (<vl> ^airborne *no*
          ^debug-x { <= <x2> >= <x1> }
          ^debug-y { <= <y2> >= <y1> }
          -^counted
       )
-->
(<s> ^operator <o> +, = )
(<o> ^name count-plane
     ^object <vl>
  )
(write (crlf) |propose count one more in group| )
)

#####################################################################
# apply count operator
#####################################################################
sp (cm*count*apply
      (state <s> ^top-state <ts>
                 ^operator <o>
         )
           (<ts> ^group.<act1>.lat1 <x1>
                 ^group.<act1>.lat2 <x2>
                 ^group.<act1>.long1 <y1>
                 ^group.<act1>.long2 <y2>
                 ^group.<act1> <gcl>
                 ^group.number <n1>
              )
           (<gcl> ^count <ctl>
                  ^sum-x <x5>
                  ^sum-y <y5>
         )
        (<o> ^name count-plane
             ^object <vl>
        )
       (<vl> -^counted
             ^debug-x { <= <x2> >= <x1> }
             ^debug-y { <= <y2> >= <y1> }
             ^debug-x <xx1>
             ^debug-y <yy1>

       )
-->
(<vl> ^counted (+ 1 <ctl> ) )
(<gcl> ^count <ctl> -
            ( + <ctl> 1 )
       ^sum-x <x5> -
       ^sum-x (+ <x5> (/ <xx1>  <n1> ) )
       ^sum-y <y5> -
       ^sum-y (+ <y5> (/ <yy1>  <n1> ) )
  )

#(interrupt)
)
##########################################################################
# assign first group to look at
##########################################################################
sp (cm*ccount*apply*assign-active-group
      (state <s> ^top-state <ts>
                 ^operator <o>
         )
           (<ts> ^group.<act1>.lat1 <x1>
                 ^group.<act1>.lat2 <x2>
                 ^group.<act1>.long1 <y1>
                 ^group.<act1>.long2 <y2>
                 ^group.<act1> <gcl>
                 ^group.number <n1>
                -^group.active
                 ^group <grp>
           )
#          (<gcl> ^count <ctl>
#                 ^sum-x <x5>
#                 ^sum-y <y5>
#           )
            (<o> ^name count-plane
                 ^object <vl>
           )
          (<vl>  ^debug-x { <= <x2> >= <x1> }
                 ^debug-y { <= <y2> >= <y1> }
          )
-->
(<grp> ^active <act1> )
)
##########################################################################
# assign second group to look at
##########################################################################
sp (cm*ccount*apply*assign-next-active-group
      (state <s> ^top-state <ts>
                 ^operator <o>
         )
           (<ts> ^group.<act1>.lat1 <x1>
                 ^group.<act1>.lat2 <x2>
                 ^group.<act1>.long1 <y1>
                 ^group.<act1>.long2 <y2>
                 ^group.<act1> <gcl>
                 ^group.number <n1>
```

```
          ^group.active { <active1> <> <act1> }
         -^group.next
          ^group <grp>
     )
#    (<gc1> ^count <ct1>
#           ^sum-x <x5>
#           ^sum-y <y5>
#     )
      (<o> ^name count-plane
           ^object <v1>
     )
     (<v1>  ^debug-x { <= <x2> >= <x1> }
            ^debug-y { <= <y2> >= <y1> }
     )
-->
(interrupt)
(<grp> ^next <act1> )
)

##################################################
#  terminate count
##################################################
sp (cm*count*terminate
      (state <s> ^top-state <ts>
                 ^operator <o>
        )
        (<o> ^name count-plane
             ^object <v1>
       )
      (<v1> ^counted <c1> )
-->
(<s> ^operator <o> @ )
(write (crlf) | detect part of cluster  | <c1>  )
)
#########################################################
# airfield found when count in both groups matches total
#########################################################
sp (cm*found*cluster
    (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    ( <ts>  ^group.<g2> <g3>
            ^group.number <c1>
            ^group <g1>
           #-^found-airfield
    )
    (<g1> ^cluster-count <ccc> )
    (<g3> ^count <c1>
          -^cluster
 )

 -->
 ( <g1> ^cluster-count <ccc> -
                     (+ 1 <ccc> )
  )
 ( <g3> ^cluster *yes* )
#(<ts> ^found-airfield *yes* )
(write (crlf) | identified cluster | <g2> )
)

##########################################################
# airfield found when count in one group matches total
##########################################################
sp (cm*found*airfield
    (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    ( <ts>  ^group.cluster-count 1
```

```
             -^found-airfield
    )
-->
(<ts> ^found-airfield *yes* )
(write (crlf) | found airfield | )
)

######################################################################
# slow cursor NFOV cursor
############################################################
sp (cm*slow-nfov-cursor*set-time
     (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
    (<ts> ^current-time.value <ct>
          ^parameter.criteria <crit>
          ^vision.object <pl1>
          ^found-airfield <fa>
          ^group.active <act1>
          ^group.<act1>.cluster *yes*
          -^slow-cursor
 )
-->
  (write (crlf) |********slowing NFOV cursor done in 2 seconds| )
 (<ts>  ^slow-cursor (+ 2 <ct> )
    )
)

#############################################################
# calculate r and theta for each plane
#############################################################
sp (cm*claculate*radius-and-theta
    (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
        (<ts> ^group.<act1>.lat1 <x1>
              ^group.<act1>.lat2 <x2>
              ^group.<act1>.long1 <y1>
              ^group.<act1>.long2 <y2>
              ^group.<act1> <gc1>
              ^group.number <n1>
              ^vision.object <pl1>
              ^found-airfield <fa>
              ^group.active <act1>
              ^group.<act1>.cluster *yes*
              ^parameter.rtic <rt>
        )
       (<gc1> ^count <ct1>
              ^sum-x <xc>
              ^sum-y <yc>
        )
        (<pl1> -^r
               ^debug-x { <= <x2> >= <x1> }
               ^debug-y { <= <y2> >= <y1> }
               ^debug-x <xx1>
               ^debug-y <yy1>

        )
 -->

   (<pl1> ^r (sqrt (+ (* (- <xc> <xx1> ) (- <xc> <xx1> ) ) (* (- <yc> <yy1> )
  (- <yc> <yy1> ) ) ) ) )
  (<pl1> ^theta (atan2 (- <yy1> <yc> ) (- <xx1> <xc> ) ) )
 )

#############################################################
# propose slewing motor delay complete
```

```
##########################################################
sp {cm*done-slewing*propose
      (state <s> ^top-state <ts> )
  -(state <ss> ^superstate <s> ^type state)
   (<ts> ^current-time.value <ct>
         ^slew-cursor <ds> <= <ct>
         -^nfov
      )
-->
(<s> ^operator <o> +, = )
(<o> ^name done-slewing )
}
######
sp {done-slewing*apply
      (state <s> ^operator <o>
                 ^top-state <ts>
      )
     (<o> ^name done-slewing )
-->
(<ts> ^nfov *yes* )
}
######
sp {cm*done-slewing*terminate
      (state <s> ^operator <o>
                 ^top-state <ts>
      )
            (<o> ^name done-slewing )
           (<ts> ^nfov <nt> )
-->
(write (crlf) | ---FLIR NFOV ENGAGED ---   |  )
(<s> ^operator <o> @ )
}

###########################################################
# detect and identify specific planes
###########################################################
#
############################################
# propose to look at one of the planes
# active = actively looking/looked at plane
############################################
sp {cm*probability*initialize-active-agent*propose
    (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    (<ts> ^current-time.value <ct>
          ^vision.object <v1>
          ^parameter.zzzstartattacktime
          -^parameter.not-ok-to-look
          ^group.active <act1>
          ^group.<act1>.lat1 <x1>
          ^group.<act1>.lat2 <x2>
          ^group.<act1>.long1 <y1>
          ^group.<act1>.long2 <y2>
         -^group.<act1>.erase
          ^nfov <fa>
#          ^baseline *yes*
       )
    (<v1> ^debug-x { >= <x1> <= <x2> }
          ^debug-y { >= <y1> <= <y2> }
          ^airborne *no*
          -^active
          -^stats
       )
 -->
 (<s> ^operator <o> +,  =  )
 (<o> ^name sort-cog-model
```



```
         ^object <v1>
   )
(write (crlf) |choose one plane to classify and identify  | )
}

################################################
# select plane to look at and mark as active
################################################
sp {cm*sort*cogmodel*apply
     (state <s> ^top-state <ts>
                ^operator <o>
      )
         (<ts> ^current-time.value <ct>
               ^parameter <p3>
          )
         (<p3> -^not-ok-to-look )
         (<o> ^name sort-cog-model
              ^object <v1>
          )
         (<v1> -^active)
-->
(<v1> ^active *yes*
      ^look-wait <ct>
 )
(<p3> ^not-ok-to-look 1 )
}

################################################
# terminate operator sort-cog-model
################################################
sp {cm*sort*cogmodel*terminate
     (state <s> ^top-state <ts>
                ^operator <o>
      )
      (<o> ^name sort-cog-model
           ^object <v1>
       )
     (<v1> ^active *yes* )
-->
(<s> ^operator <o> @ )
(write (crlf) | done selecting object to look at | )
#(interrupt)
}

######################################################
# initialization values
######################################################
#sp {cm*probability*initialize-active-agent
#    (state <s> ^top-state <ts>)
#  -(state <ss> ^superstate <s> ^type state)
#   (<ts> ^current-time.value <ct>
#         ^vision.object <v1>
#         ^parameter.zzzstartattacktime
#      )
#   (<v1> ^airborne *no*
#         ^slant-range <r1>
#         -^id-class
#         -^prob-range-class
#         -^prob-range-update
#         ^active *yes*
#      )
#   (<r1> ^value <v2>)
#-->
#  (<v1> ^prob-range-class 0.1
#        ^prob-range-plane 0.1
```

```
#        ^prob-range-update <ct>
#
#      )
#(interrupt)
#)

##################################################################
# close enough to actually classify as at least a plane
##################################################################
sp (cm*detect-plane-print
    (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    (<ts> ^current-time.value <ct>
          ^vision.object <v1>
          ^parameter.zzzstartattacktime
     )
    (<v1> ^airborne *no*
          ^active *yes*
          ^slant-range <r1>
          -^id-class
          ^detect-range <dr> < <v2>
#          ^prob-range-class <prc>
#          ^prob-range-update <pru> < <ct>
     )
     (<r1> ^value <v2>)
 -->
 (write (crlf) | detect range is |(* 3.2787 <v2> ) | at time | <ct> | prob =
 | )
 # (- 2.3 (* 0.0000000022 (* 3.2787 (* <v2> <v2> ) ) ) ) )
 #  (<v1> ^prob-range-class <prc> -
 #            (- 2.3 (* 0.0000000022 (* 3.2787 (* <v2> <v2> ) ) ) ) +
 #
 #        ^prob-range-update <pru> -
 #                                 <ct> +
 #
 #     )
 #(interrupt)
 #
 )
 ###############################################################
 # tag plane as detected
 ###############################################################
 sp (cm*mark*class-id
      (state <s> ^top-state <ts>)
    -(state <ss> ^superstate <s> ^type state)
     (<ts> ^current-time.value <ct>
           ^parameter.criteria <crit>
           ^vision.object <pl1>
           ^cog-model.data <d3>
      )
     (<d3> ^detect-time <dt>)
     (<pl1> ^slant-range.value <val>
            ^detect-range <dr> > <val>
            -^id-class
           ^look-wait <lw> < <ct>
           ^active *yes*
  )
  -->
   (write (crlf) | detected plane: | <pl1> | times: | <lw> | | <ct> )
   (<pl1>  ^id-class *yes*  )
  )
  ###############################################################
  sp (cm*mark*class-id*record-first-detection
       (state <s> ^top-state <ts>)
     -(state <ss> ^superstate <s> ^type state)
      (<ts> ^current-time.value <ct>
            ^parameter.criteria <crit>
            ^vision.object <pl1>
```

```
          ^cog-model.data <d3>
          ^waypoint.computer.range.value <va2>
     )
   (<d3> -^detect-time )
   (<pl1> ^slant-range.value <val>
          ^detect-range <dr> > <val>
          -^id-class
         ^look-wait < <ct>
         ^active *yes*
 )
-->
 ( <d3> ^detect-time <ct>
        ^detect-range (* 3.2787 <val> )
        ^detect-rrange (* 3.2787 <va2> )
  )
 (write (crlf) | detected first plane: | <pl1> )
 (<pl1>  ^id-class *yes*  )
)

##################################################################################
###################################################
#######################################################
# compare rtic information true
#######################################################
sp (cm*rtic*compare-true
      (state <s> ^top-state <ts>
                 ^problem-space.name wait )
#  -(state <ss> ^superstate <s> ^type state)
    (state <s2> ^problem-space.name fly-attack )
    (<ts> ^vision.object <pl1>
          ^parameter.rtic <rt>
          ^group.active <act>
          ^group.<act> <grl>
          ^cog-model.data <d3>
     )
    (<pl1> ^id-class
           -^stats
            ^r ( <= <r2> >= <r1> )
            ^theta ( <= <a2> >= <a1> )
     )
  (<grl> ^rtic <rtic>)
   (<rtic> ^r1 <r1>
           ^r2 <r2>
           ^a1 <a1>
           ^a2 <a2>
    )
  (<d3> ^hit-count <hc> )
  -->
  (write (crlf) | ---------HIT--------  | )
  (<d3>  ^hit-count <hc> -
                   (+ <hc> 1) + )
  (<pl1> ^stats hit)
  ( <s2> ^in-cone-missile *yes* )
  )
  #####################################################
  # compare rtic information false
  #####################################################
  sp (cm*rtic*compare-false
        (state <s> ^top-state <ts>
                   ^problem-space.name wait )
  #  -(state <ss> ^superstate <s> ^type state)
      (<ts> ^vision.object <pl1>
            ^parameter.rtic <rt>
            ^parameter <par>
            ^group.active <act>
            ^group.<act> <grl>
```

```
       ^cog-model.data <d3>
     )
   (<pl1> ^id-class
         -^stats
     )
  -(<pl1> ^r { <= <r2> >= <r1> }
          ^theta { <= <a2> >= <a1> }
    )
(<par> ^not-ok-to-look <ok1> )
(<gr1> ^rtic <rtic>)
  (<rtic> ^r1 <r1>
          ^r2 <r2>
          ^a1 <a1>
          ^a2 <a2>
  )
(<d3> ^cr-count <cr3>)
-->
(<d3> ^cr-count <cr3> -
             (+ <cr3> 1)
)
(write (crlf) | ---------CR----------- | )
(<pl1> ^stats cr )
(<par> ^not-ok-to-look <ok1> - )
)

##################################################
# calculate ability to identity plane
##################################################
sp {cm*probability*id-plane*monitor
    (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    (<ts> ^current-time.value <ct>
          ^vision.object <v1>
          ^parameter.zzzstartattacktime
          ^parameter.baseline *yes*
       )
    (<v1> ^airborne *no*
          ^slant-range.value <r1>
          ^active *yes*
          ^id-range <ir> < <r1>
#           ^slow-done *yes*
          ^id-class <ic>
          -^id-plane
#           ^prob-range-plane <pp>
#           ^prob-range-update <pu> < <ct>
      )
-->
(write (crlf) | identify range is |(* 3.2787 <r1> ) | at time | <ct> )

#| prob = | (- 2.0 (* 0.0000000022 (* 3.2787 (* <r1> <r1> ) ) ) ) )
#  (<v1> ^prob-range-plane <pp> -
                          (- 2.0 (* 0.0000000022 (* 3.2787 (* <v2> <v2> ) )
#
) ) +
#        ^prob-range-update <pu> -
#                          <ct> +
#
#     )
#(interrupt)
}

#########################################################
# tag plane as identified
#########################################################
sp {attack-delivery*elaborate*head-toward-target*maverick
     (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
    (state <s2> ^problem-space.name attack-delivery )
```

```
          (<ts> ^current-time.value <ct>
                ^parameter.criteria <crit>
                ^parameter.baseline *yes*
                ^vision.object <pl1>
                ^group.active <act1>
                ^group.<act1> <gr3>
                ^cog-model.data <d3>
            )
         (<d3> ^ident-time <dt>)
         (<gr3> ^count-id <ic3>)
         (<pl1> ^id-range <id1> > <sr1>
                ^slant-range.value <sr1>
                ^id-class <ic>
               -^id-plane
                ^active *yes*
)
-->
# (<gr3> ^count-id <ic3> -
#                (+ <ic3> 1 )
#    )
   (write (crlf) | identified  plane: | <pl1> )
  (<pl1> ^id-plane *yes*
     )
  ( <s2> ^in-cone-missile *yes* )
}
sp {attack-delivery*elaborate*head-toward-target*maverick*record-first
     (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    (state <s2> ^problem-space.name attack-delivery )
          (<ts> ^current-time.value <ct>
                ^parameter.zzzstartattacktime <zz>
                ^parameter.baseline *yes*
                ^vision.object <pl1>
                ^group.active <act1>
                ^group.<act1> <gr3>
                ^cog-model.data <d3>
                ^waypoint.computer.range.value <srr1>
            )
         (<d3> -^ident-time <dt>)
         (<gr3> ^count-id <ic3>)
         (<pl1> ^id-range <id1> > <sr1>
                ^slant-range.value <sr1>
                ^id-class <ic>
               -^id-plane
                ^active *yes*
  )
 -->
 (<d3> ^ident-time (- <ct> <zz> )
       ^ident-range (*  3.2787 <sr1> )
       ^ident-rrange (*  3.2787 <srr1> )
 )
 # (<gr3> ^count-id <ic3> -
 #                (+ <ic3> 1 )
 #   )
   (write (crlf) | identified  plane: | <pl1> )
  (<pl1> ^id-plane *yes*
     )
  ( <s2> ^in-cone-missile *yes* )
}

#########################################################
# after identify plane, decide if decision
# made was correct based on random number generator,
#                and distance to object
#########################################################
sp {cm*calculte-random
```

```
      (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
   (<ts> ^current-time.value <ct>
         ^parameter.criteria <crit>
         ^vision.object <pl1>
         ^cog-model.m <m>
         ^cog-model.b <b>
   )
   (<pl1> ^slant-range.value <sr1>
          ^id-plane *yes*
          -^dice-results
      )
-->
   (write (crlf) |**** b: | <b> | m: | <m> | range: | <sr1> | percent | <cri
t> | % Capable of Identifying plane | )
   (<pl1> ^dice-results (/ (mod (abs (int (* (sin <ct>) 1000000) ) ) 100 ) 1
00 )
          ^probability (+ <b> (* <m> <sr1>  ) )
   )
#(interrupt)
)

##################################################################
##################################################################
##  productions for calculating hit, miss, fa, cr
##  id_range is 13,000 +/- 2000 (stdev?)
##  id is 90% at id-mean
##  Id is 100% at id-mean - 2*stdev
##  id is 80% at  id-mean + 2*stdev
##  p = 1.225 - .2/8000*slant-range
##################################################################
##################################################################
sp (cm*no-hits1
      (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
   (<ts> ^parameter <p3>
         ^vision.object <pl1>
         ^cog-model.data <d3>
         ^group.active <act1>
         ^group.<act1> <gr3>
   )
   (<gr3> ^count-id <idc3>
          ^count <idc3>
     )
   (<p3> -^not-ok-to-look )
   -(<pl1> ^stats hit )
-->
 (write (crlf) | FUBAR | )
 (<gr3> ^erase 0
        ^count-id <idc3> -
                0 +
)
#(<p3> ^not-ok-to-look <ok1> - )
#(interrupt)
)
sp (cm*no-hits-erase
      (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
   (<ts> ^parameter <p3>
         ^vision.object <pl1>
         ^cog-model.data <d3>
         ^group.active <act1>
         ^group.<act1> <gr3>
    )
   (<gr3> ^erase <or1>
#          ^count-id <cit>

    )
   (<pl1> ^stats <st3>
          ^look-wait <lw3>
          ^id-class <idc3>
          ^id-plane <idp3>
          ^dice-results <dice>
          ^probability <prb>
)
-->
(write (crlf) | FUBAR erase | <pl1> )
   (<pl1> ^stats <st3> -
          ^look-wait <lw3> -
          ^id-class <idc3> -
          ^id-plane <idp3> -
          ^dice-results <dice> -
          ^probability <prb> -
  )
#(interrupt)
)
##########################################################
sp (cm*no-hits-recover
      (state <s> ^top-state <ts>)
  -(state <ss> ^superstate <s> ^type state)
   (<ts> ^parameter <p3>
         ^vision.object <pl1>
         ^cog-model.data <d3>
         ^group.active <act1>
         ^group.<act1> <gr3>
    )
   (<gr3> ^erase <or3> )
  -(<pl1> ^stats )
-->
 (write (crlf) | FUBAR done | )
 (<gr3> ^erase <or3> - )
 #(interrupt)
 )

 sp (cm*calculate-hitmiss
       (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    (<ts> ^parameter <p3>
          ^vision.object <pl1>
          ^cog-model.data <d3>
          ^group.active <act1>
          ^group.<act1> <gr3>
     )
    (<gr3> ^count-id <ic3>)
    (<p3> ^criteria <crit>
          ^not-ok-to-look <ok1>
     )
    (<pl1> ^probability <prp>
           ^dice-results <dr> > <prp>
           ^object-type kc-10a
           ^active <actv>
           -^stats
    )
     (<d3> ^miss-count <fa3> )
 -->
  (<gr3> ^count-id <ic3> -
                   (+ <ic3> 1 )
   )
 (write (crlf) | ---MISS--- | <dr> | > | <prp> )
  (<d3> ^miss-count <fa3> -
                  (+ <fa3> 1) +
  )
 (<pl1> ^stats miss
```

```
       ^active <actv> -
  )
 (<p3> ^not-ok-to-look <okl> - )
 #(interrupt)
 }

 ##########################################
 sp {cm*calculate-cr
         (state <s> ^top-state <ts>)
   -(state <ss> ^superstate <s> ^type state)
    (<ts> ^parameter <p3>
          ^vision.object <pl1>
          ^cog-model.data <d3>
          ^group.active <act1>
          ^group.<act1> <gr3>
        )
    (<gr3> ^count-id <ic3> )
     (<p3> ^criteria <crit>
          ^not-ok-to-look <okl>
      )
     (<pl1>  ^probability <prp>
           ^dice-results <dr> < <prp>
           -^object-type kc-10a
           ^active <actv>
           -^stats
    )
     (<d3> ^cr-count <cr3> )
 -->
  (<gr3> ^count-id <ic3> -
                  (+ <ic3> 1 )
     )
  (write (crlf) | ---CR--- | <dr> | < | <prp> )
  (<pl1> ^stats cr
        ^active <actv> -
     )
  (<d3> ^cr-count <cr3> -
                  (+ <cr3> 1) +
   )
  (<p3> ^not-ok-to-look <okl> - )
  #(interrupt)
  }

  ##################################################
  sp {cm*calculate-fa
        (state <s> ^top-state <ts>)
    -(state <ss> ^superstate <s> ^type state)
     (<ts> ^parameter.criteria <crit>
           ^vision.object <pl1>
           ^cog-model.data <d3>
           ^group.active <act1>
           ^group.<act1> <gr3>
      )
    (<gr3> ^count-id <ic3>)
    (<pl1>  ^probability <prp>
            ^dice-results <dr> >= <prp>
            -^object-type kc-10a
            ^active <actv>
            -^stats
     )
   (<d3> ^fa-count <fa3> )
  -->
   (<gr3> ^count-id <ic3> -
                  (+ <ic3> 1 )
     )
   (write (crlf) | ---FA--- | <dr> | >= | <prp> )
    (<d3> ^fa-count <fa3> -
```

```
                    (+ <fa3> 1) +
 )
(<pl1> ^stats fa
       ^active <actv> -
  )
#(interrupt)
}

##########################################################
sp {cm*calculate-hit
        (state <s> ^top-state <ts>)
     -(state <ss> ^superstate <s> ^type state)
              (<ts> ^parameter <pl>
                    ^vision.object <pl1>
                    ^cog-model.data <d3>
                )
              (<d3> ^hit-count <hc>
                )
             (<pl1> ^probability <prp>
                    ^dice-results <dr> < <prp>
                    ^object-type kc-10a
                    ^active <actv>
                    -^stats
                )
 -->
  (write (crlf) | ---HIT--  | <dr> | < | <prp> )
  (<pl1> ^stats hit
         ^active <actv> -
   )
   (<d3> ^hit-count <hc> -
                    (+ <hc> 1) +
      )
  }

  ########################################################
  ########################################################
  # propose designation
  ########################################################
  sp {cm*designate-propose-hit
         (state <s> ^top-state <ts>
                    ^problem-space.name wait )
  #    -(state <ss> ^superstate <s> ^type state)
               (<ts> ^vision.object <pl1>
                     ^parameter <pl>
  #               )
                (<pl> ^hit-count <hc> )
  #           (<pl1> ^stats hit
                     -^designate )
  -->
   (<s> ^operator <o> +, = )
   (<o> ^name designate
        ^plane <pl1>
     )
   }

   ######################################################
   # propose designation even if false alarm
   ######################################################
   sp {cm*designate-propose-fa
        (state <s> ^top-state <ts>
                   ^problem-space.name wait )
   #  -(state <ss> ^superstate <s> ^type state)
      (<ts> ^vision.object <pl1>
          )
      (<pl1> ^stats fa
```

```
        -^designate )
-->
(<s> ^operator <o> +, = )
(<o> ^name designate
     ^plane <pl1> )
)

##########################################################
# designate operator
##########################################################
sp (cm*designate-apply
      (state <s> ^operator <o>
                 ^top-state <ts>)
     (<o> ^name designate
          ^plane <pl1>
      )
    (<ts> ^parameter.criteria <crit>
          ^current-time.value <ct>
          ^vision.object <pl1>
     )
 -->
 (<pl1> ^designate <ct>
      )
 #(interrupt)
 )

#####################################################
# Terminate designate operator
#####################################################
sp (cm*designate*terminate
      (state <s> ^operator <o>
                 ^top-state <ts>
        )
            (<o> ^name designate
                 ^plane <pl1>
             )
            (<pl1> ^designate <ds>)
 -->
 (write (crlf) | ---Designate---  | )
 (<s> ^operator <o> @ )
 )


###########################################################
# propose confirm operator
###########################################################
sp (cm*confirm-propose
      (state <s> ^top-state <ts> )
   -(state <ss> ^superstate <s> ^type state)
    (<ts> ^vision.object <pl1>
          ^current-time.value <ct>
  )
    (<pl1> ^designate <ds> < <ct>
           -^confirm
      )
 -->
 (<s> ^operator <o> +, = )
 (<o> ^name confirm
      ^plane <pl1> )
 )

###############################################
#  If first confirmed designation
#   then note time
```

```
##############################################
sp (cm*confirm-apply-first
      (state <s> ^operator <o>
                 ^top-state.parameter <p1>
                 ^top-state.cog-model.data <d3>
                 ^top-state.current-time.value <ct>
                 ^top-state.waypoint.computer.range.value <lrr>
     )
        (<o> ^name confirm
             ^plane <pl1>
         )
       (<p1> ^designate-count <ds> < 1
             ^zzzstartattacktime <t2>
             ^not-ok-to-look <nl>
         )
      (<pl1> -^confirm
             ^lateral-range.value <lr>
       )
-->
      (<pl1> ^confirm (+ 1 <ds> ) + )
       (<p1> ^designate-count <ds> -
                          (+ 1 <ds> ) +
             ^not-ok-to-look <nl> -
                  (+ 1 <nl> ) +

       )
      (<d3> ^designate1-time (- <ct> <t2> )
            ^designate1-range (* <lr> 3.2787 )
            ^designate1-rrange (* <lrr> 3.2787 )
       )
 )
##############################################
#  note plane confirmed
##############################################
sp (cm*confirm-apply-rest
      (state <s> ^operator <o>
                 ^top-state.parameter <p1>
                 ^top-state.cog-model.data <d3>
                 ^top-state.current-time.value <ct>
                 ^top-state.waypoint.computer.range.value <lrr>
     )
        (<o> ^name confirm
             ^plane <pl1>
         )
       (<p1> ^designate-count <ds> > 0
#            ^not-ok-to-look <nl>
             ^zzzstartattacktime <t2>
        )
      (<pl1> -^confirm
             ^lateral-range.value <lr>
 )
 -->
 (<pl1> ^confirm (+ 1 <ds> ) )
 (<p1> ^designate-count <ds> -
                       (+ 1 <ds> ) +

#       ^not-ok-to-look <nl> -
#                      (+ 1 <nl> ) +
   )
      (<d3> ^designate2-time (- <ct> <t2> )
            ^designate2-range (* <lr> 3.2787 )
            ^designate2-rrange (* <lrr> 3.2787 )
       )
 )
```

```
##########################################
#  terminate confirm operator
##########################################
sp (cm*confirm-terminate
      (state <s> ^operator <o>
                 ^top-state.parameter <p1>
      )
          (<p1> ^designate-count <ds> )
           (<o> ^name confirm
                ^plane <pl1> )
         (<pl1> ^confirm <ds2>)
-->
(write (crlf) | ---Designate Confirmed--- | <ds>  )
(<s> ^operator <o> @ )
)

######################################################
# Finished confirming designation, ready for next group
#                      or launch
######################################################
sp (cm*ready-to-look-at-next
      (state <s> ^top-state <ts>
                 ^operator <o>
      )
          (<ts> ^current-time.value <ct>
                ^parameter <p3>
                ^group <gl>
                ^slew-cursor <sc>
                ^nfov <nf>
          )
          (<gl> ^active <acl>
                 ^next <nxl>
#
)
          (<p3> ^not-ok-to-look <la> > 1 )
         -(<o> ^name confirm )
-->
(<ts> ^slew-cursor <sc> -
      ^nfov <nf> -
)
(<gl> ^active <acl> -
#123       ^active <nxl> +
)
(<p3> ^not-ok-to-look <la> - )
(write (crlf) | ---back to  WFOV ENGAGED ---   |  )
)

##########################################
# lock and launch mavericks
##########################################
# note proceding to locking maverick 1
#     set motor delay
##########################################
sp (cm*lock-delay-first
      (state <s> ^top-state <ts> )
    -(state <ss> ^superstate <s> ^type state)
           (<ts> ^parameter <p1>
                 ^current-time.value <ct>
                 ^vision.object <pl1>
           )
        (<pl1> -^lock-wait
                ^confirm 1
         )
          (<p1> ^designate-count <dc> > 1
                ^lock-count < 1

               )
-->
(write (crlf) |---switching to lock procedures-1-- |)
(<pl1> ^lock-wait (+ <ct> 2) )
)
##############################################
# motor delay for locking mavericks
##############################################
sp (cm*lock-delay-first
      (state <s> ^top-state <ts> )
    -(state <ss> ^superstate <s> ^type state)
          (<ts> ^parameter <p1>
                ^current-time.value <ct>
                ^vision.object <pl1>
          )
       (<pl1> -^lock-wait
               ^confirm 1
        )
         (<p1> ^designate-count <dc> > 1
               ^lock-count < 1

              )
-->
(write (crlf) |---switching to lock procedures-1-- |)
(<pl1> ^lock-wait (+ <ct> 1 ) )
)
######################################
# note proceding to locking maverick 2
#     set motor delay
######################################
sp (cm*lock-delay-second
      (state <s> ^top-state <ts> )
    -(state <ss> ^superstate <s> ^type state)
          (<ts> ^parameter <p1>
                ^current-time.value <ct>
                ^vision.object <pl1>
          )
       (<pl1> -^lock-wait
               ^confirm 2
        )
         (<p1> ^designate-count <dc> > 1
               ^lock-count > 0

              )
-->
(write (crlf) |---switching to lock procedures-2-- |)
(<pl1> ^lock-wait (+ <ct> 1 ) )
)

##################################################
# propose lock mavericks
##################################################
sp (cm*lock-one-propose
      (state <s> ^top-state <ts> )
    -(state <ss> ^superstate <s> ^type state)
          (<ts> ^vision.object <pl1>
                ^current-time.value <ct>
      )
          (<pl1>  ^lock-wait <lw> < <ct>
                  ^confirm <cf>
                 -^lock
             )
-->
(<s> ^operator <o> +, = )
(<o> ^name lock
```

```
     ^plane <pl1> )
(write (crlf) |--- locking maverick-| <cf> |-- |)
)

##############################################################
#  note locked only 1 maverick
##############################################################
sp (cm*lock-apply-first
      (state <s> ^operator <o>
                 ^top-state.parameter <p1>
                 ^top-state.current-time.value <ct>
                 ^top-state.cog-model.data <d3>
                 ^top-state.waypoint.computer.range.value <lkrr1>
         )
            (<o> ^name lock
                 ^plane <pl1>
            )
           (<p1> ^lock-count <lc> 0
                 ^zzzstartattacktime <ot1>
          )
         (<pl1> -^lock
                 ^slant-range.value <lkr1>
          )
 -->
 (write (crlf) | locked 1 data | )
 (<pl1> ^lock (+ <lc> 1) )
 (<p1> ^lock-count <lc> -
                           (+ 1 <lc> ) +
    )
 (<d3> ^lock1-time (- <ct> <ot1> )
       ^lock1-range (* <lkr1> 3.2787 )
       ^lock1-rrange (* <lkrr1> 3.2787 )
  )
 )
####################################################
# lock second maverick
####################################################
sp (cm*lock-apply-second
      (state <s> ^operator <o>
                 ^top-state.parameter <p1>
                 ^top-state.current-time.value <ct>
                 ^top-state.cog-model.data <d3>
                 ^top-state.waypoint.computer.range.value <lkrr1>
         )
            (<o> ^name lock
                 ^plane <pl1>
            )
           (<p1> ^lock-count <lc> 1
                 ^zzzstartattacktime <ot1>
          )
         (<pl1> -^lock
                 ^slant-range.value <lkr1>
          )
 -->
 (write (crlf) | locked 2 data | )
 (<pl1> ^lock (+ <lc> 1) )
 (<p1> ^lock-count <lc> -
                           (+ 1 <lc> ) +
    )
 (<d3> ^lock2-time (- <ct> <ot1> )
       ^lock2-range (* 3.2787 <lkr1> )
       ^lock2-rrange (* 3.2787 <lkrr1> )
  )
 )

##########################################################

# terminate lock maverick operator
##########################################################
sp (cm*lock-terminate
      (state <s> ^operator <o> )
            (<o> ^name lock
                 ^plane <pl1>
            )
         (<pl1> ^lock <dl>)
-->
(write (crlf) | ---Confirmed locked--- | <dl>  )
(<s> ^operator <o> @ )
)

##############################################################
#  launch mavericks
####################################
sp (cm*launch-delay
      (state <s> ^top-state <ts> )
    -(state <ss> ^superstate <s> ^type state)
        (<ts> ^parameter <p1>
              ^current-time.value <ct>
          )
         (<p1> ^designate-count <dc1>
               ^lock-count <dc1> > 0
              -^launch-wait
          )
 -->
  (write (crlf) |---switching to launch procedures--- | )
  (<p1> ^launch-wait (+ <ct> 1 ) )
 #(interrupt)
 )

##############################################################
# watch range symbol, launch and print dependent measures
##############################################################
sp (cm*watch-range-symbol
      (state <s> ^top-state <ts> )
    -(state <ss> ^superstate <s> ^type state)
     (state <s2> ^problem-space.name fly-attack )
         (<ts> ^parameter <p1>
                ^current-time.value <ct>
                ^vision.object <pln1>
                ^cog-model.data <d3>
                ^cog-model.max-mav-range <mmr>
          )
          (<p1> ^launch-wait <lw> < <ct>
               -^launched
          )
    (<pln1> ^slant-range.value > <mmr>
            ^confirm <yes>
     )
    (<pln1> ^slant-range.value <slv>)
 -->
 (write (crlf) |--- watching range icon---|)
 )
##############################################################
sp (cm*watch-range-symbol-assign-in-cone
      (state <s> ^top-state <ts> )
    -(state <ss> ^superstate <s> ^type state)
     (state <s2> ^problem-space.name attack-delivery
               -^in-cone-missile
      )
         (<ts> ^parameter <p1>
               ^current-time.value <ct>
               ^vision.object <pln1>
               ^cog-model.data <d3>
```

```
              ^cog-model.max-mav-range <mmr>
        )
      (<p1> ^launch-wait <lw> < <ct>
            -^launched
        )
  (<pln1> ^slant-range.value > <mmr>
          ^confirm <yes>
    )
  (<pln1> ^slant-range.value <slv>)
-->
(<s2> ^in-cone-missile *yes* )
(write (crlf) |--- watching range icon---|)
)
################################################################
sp {cm*launch-and-print-data
     (state <s> ^top-state <ts> )
   -(state <ss> ^superstate <s> ^type state)
   (state <s2> ^problem-space.name attack-delivery )
      (<ts> ^parameter <p1>
               ^current-time.value <ct>
               ^vision.object <pln1>
               ^cog-model.data <d3>
               ^cog-model.max-mav-range <mmr>
               ^cog-model.trialnum1 <trn>
               ^waypoint.computer.range.value <slvr>
               ^group.<first>.count <cnt1> > 2
               ^group.active { <second> <> <first> }
#               ^group <first>
#               ^group { <second> <> <first> }
       )
       (<p1> ^launch-wait <lw> < <ct>
             -^launched
#               ^designate-time <ds1>
#               ^hit-count <hc1>
              ^zzzstartattacktime <zz>
        )
        (<d3> ^hit-count <hc3>
                ^cr-count <cr3>
                ^miss-count <mc3>
                ^fa-count <fa3>
                ^detect-time <dtt1>
                ^detect-range <dtr1>
                ^detect-rrange <dtrr1>
                ^ident-time <idt1>
                ^ident-range <idr1>
                ^ident-rrange <idrr1>
                ^designate1-time <dgt1>
                ^designate1-range <dgr1>
                ^designate1-rrange <dgrr1>
                ^designate2-time <dgt2>
                ^designate2-range <dgr2>
                ^designate2-rrange <dgrr2>
                ^lock1-time <lkt1>
                ^lock1-range <lkr1>
                ^lock1-rrange <lkrr1>
                ^lock2-time <lkt2>
                ^lock2-range <lkr2>
                ^lock2-rrange <lkrr2>
                ^behavior <bhv>
         )
   (<pln1> ^slant-range.value < <mmr>
             ^confirm 1
    )
   (<pln1> ^slant-range.value <slv>
            ^debug-x <xx3>
    )
-->
(<s2> ^locked *yes*
      ^visual-target <pln1>
      ^processed-target <pln1>
 )
(<p1> ^launched *yes*)
#(<s> ^operator <o> +, = )
#(<o> ^name launch
#     ^plane <p1> )
(write (crlf) |--- push fire button at time -| (- <ct> <zz> ) |-- |)
(write (crlf) |--- write data to file-- |)
(tcl |set fileid [open cogdata a] | )
(tcl |puts $fileid | <trn> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <hc3> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <mc3> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <fa3> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <cr3> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | (- <dtt1> <zz> ) | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <dtr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <dtrr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <idt1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <idr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <idrr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <dgt1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <dgr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <dgrr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <dgt2> | nonewline| )
(tcl |puts $fileid ",." nonewline| )
(tcl |puts $fileid | <dgr2> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <dgrr2> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <lkt1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <lkr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <lkrr1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <lkt2> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <lkr2>  | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <lkrr2> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | (- <ct> <zz> ) | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | (* 3.2787 <slv> ) | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | (* 3.2787 <slvr> ) | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <bhv> | nonewline| )
(tcl |puts $fileid ",." nonewline| )
```

```
(tcl |puts $fileid | <cnt1> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <first> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <second> | nonewline| )
(tcl |puts $fileid ", " nonewline| )
(tcl |puts $fileid | <xx3>  )
(tcl |close $fileid| )
)

###########################################################
# alter soar productions so always desire
#    speed = 480knots = 247m/s
#    altitude 7500 feet
###########################################################
sp (set-speed*apply*asap
   (state <s>  ^operator <o>
               ^route <r>
               ^top-state.vehicle.parameter.max-transit-speed.value <speed>)
   (<o> ^name set-speed ^type asap)
-->
   (write (crlf) |ASAP Mission use max-transit-speed.|)
   (<r> ^speed 247 )
)
sp (set-speed*apply*speed*min*ingress
   (state <s> ^operator <o>
              ^route <r>
              ^top-state.vehicle.parameter <params>)
   (<params> ^attack-speed <min>)
   (<r> ^type << attack ingress >>)
   (<o> ^name set-speed
        ^type time-on-point
        ^proposed-speed ( > 0 <= <min>))
   -->
   (write (crlf) |Selected attack speed.|)
   (<r> ^speed 247 )
)
sp (set-speed*apply*no-speed-ingress
   (state <s> ^operator <o>
              ^route <r>
              ^top-state.vehicle.parameter.attack-speed <speed>)
   (<o> ^name set-speed
        ^type ingress)
-->
   (write (crlf) |Selected attack speed.|)
   (<r> ^speed 247 )
)
sp (common*apply*handle-output*altitude*after*heading
   (state <s> ^top-state <ts> ^operator <o>)
   (<o> ^type output ^desired-altitude <v>
        ^achieved desired-heading)
   (<ts> ^io.output-link <ol>
        -^position.desired-altitude <v>
        -^vehicle.stalled)
-->
   (<ol> ^desired-altitude (/ 7500 3.28 ) )
   )

sp (route-tactic*apply*desired-altitude*low-medium
   (state <s>  ^operator <o>
               ^problem-space.name);# ^route.altitude << low-level medium-le
vel >>)
   (<o> ^route-tactic *yes*
        ^altitude-range.altitude-mean <ada>
       -^desired-altitude <ada>)
-->
   (write (crlf) |Low or Medium Altitude.|)
   (<o> ^desired-altitude (/ 7500 3.28 ) )
)

########################################
########################################
########################################
#modifications to make mavericks fire....
# don't need when exercise editor,
#              load-out and soar works:-(
########################################

sp (attack-delivery*propose*fire-maverick
   (state <s> ^problem-space.name attack-delivery
              ^top-state.enemy-side <e-side>
              ^processed-target <vo>
              ^visual-target <vo>
              ^in-cone-missile *yes*
              ^selected-ordnance <or>
             -^fired-on.target <vo>
              ^in-range *yes*
              ^locked *yes*
        )
########################################
# modification to fire on blue forces
########################################
   (<vo> ^force << red blue >>
        -^status *destroyed*


   )
   (<or> ^type maverick
         ^number ( > 0 <count> ))
-->
   (<s> ^operator <o> +, =)
   (<o> ^name fire-maverick
        ^count <count>
        ^type output
        ^fire-missile *yes*
        ^fire-maverick <vo>
        ^requires wait)
)

#sp (top-ps*elaborate*mission*ordnance-count
#   (state <s> ^problem-space.name top-ps
#               ^io.input-link.vehicle.munitions.munition <m>
#              ^mission.ordnance <ord>)
#  -(state <s2> ^operator.name attack-delivery)
#   (<m> ^count <n> ^type <mun>)
#   (<ord> ^type <mun>
#####added by david darkow#########
##           ^cleared-number <cn>
##         -^number
#   )
#-->
#   (<ord> ^number <n> )
##(interrupt)
#)

#12345sp (top-ps*elaborate*mission*ordnance-count-numberexists-syt
#   (state <s> ^problem-space.name top-ps
#               ^io.input-link.vehicle.munitions.munition <m>
#              ^mission.ordnance <ord>)
#   (<m> ^count <n> ^type <mun>)
#   (<ord> ^type <mun>
#          ^number <n9> < <n>
#            )
```

```
#-->
#    (<ord> ^number <n9> -
#                   <n> +
#
#)
##(interrupt)
#)

sp (plan-attack*propose*select-ordnance-force-mav1
   (state <s> ^problem-space.name plan-attack
              #^achieved-clear *yes*
              -^achieved-ordnance *yes*
              ^top-state <ts> )
   (<ts> ^mission.ordnance <or>)
   (<or> ^type maverick
        -^number
    )
-->
   (<or> ^number 2)
###123(interrupt)
)
###########################################
sp (plan-attack*propose*select-ordnance-force-mav2
   (state <s> ^problem-space.name plan-attack
              #^achieved-clear *yes*
              -^achieved-ordnance *yes*
              ^top-state <ts> )
   (<ts> ^mission.ordnance <or>)
   (<or> ^type maverick
         ^number <n1> < 2
    )
-->
   (<or> ^number <n1> -
                   2 +
    )
(interrupt)
)
###########################################
sp (plan-attack*propose*select-ordnance-force-mav3
   (state <s> ^operator <o>
              ^top-state <ts> )
#    (<o> ^name init-plane )
   (<o> ^name wait )

   (<ts> ^mission.ordnance <or>
         ^current-time.value <ct>
)
   (<or> ^type maverick
         ^number <n1> < 2
    )
-->
   (<or> ^number <n1> -
                   2 +
    )
###123(interrupt)
)
#
#sp (plan-attack*propose*select-ordnance-force-mav4
#   (state <s> ^problem-space.name attack-delivery
#              #^achieved-clear *yes*
#              ^fired-on
#              ^top-state <ts> )
#   (<ts> ^mission.ordnance <or>)
#   (<or> ^type maverick
#        -^number
#    )
```

```
#-->
#   (<or> ^number 2)
#(interrupt)
#)
#
###########################################################
sp (attack-delivery*propose*select-ordnance-new
   (state <s> ^operator <o>
              ^top-state <ts>
   )
      (<o> ^name waitt )
     (<ts> ^mission.ordnance <bl>
     )
     (<bl>  -^type maverick
             ^number <n1> > 0
     )
-->
( <bl> ^number <n1> -
                0 + )
(write (crlf) | zero | <bl> | ordnances | )
(interrupt)
)

sp (attack-delivery*propose*select-ordnance
   (state <s> ^problem-space.name attack-delivery
              ^mission.ordnance <ord>
              ^mission.attack-tactic.ordnance-type <type>
             -^attack-type harm
             -^bombs-exhausted *yes*
             -^selected-ordnance.number >= 0) ;# Change from > to >=, PEN
   (<ord> ^type <type>
          ^salvo-width <sw>
          ^bomb-impact-separation <bis>
          ^bombs-to-release <btr>
          ^number > 0)
-->
(interrupt)
   (<s> ^operator <o> + >, =)
   (<o> ^name select-ordnance
        ^ordnance <ord>
        ^salvo-width <sw>
        ^bomb-impact-separation <bis>
        ^bombs-to-release <btr>
        ^type output))

sp (top-ps*elaborate*comm*vocalize*message*tty
   "Write word or phrase to the screen"
   (state <s> ^problem-space.name top-ps
              ^comm.vocalize.message.item <sound>)
-->
#   (write | (| <sound> |)|)
)

sp (attack-delivery*elaborate*state*outside*pgm-error*left
   (state <s> ^problem-space.name attack-delivery
              ^selected-ordnance <ord>
              ^top-state <ts>)
   (<ord> ^class bomb ^pgm *yes*)
   (<ts> ^ccip <ccip>
         ^parameter <p>)
   (<ccip> ^left.value > <lr>)
   (<p> ^target-pgm-error-left-right <lr>)
-->
#   (write (crlf) |Outside error bound left|)
)
```

```
sp (attack-delivery*elaborate*state*outside*pgm-error*right
   (state <s> ^problem-space.name attack-delivery
              ^selected-ordnance <ord>
              ^top-state <ts>)
   (<ord> ^class bomb ^pgm *yes*)
   (<ts> ^ccip <ccip>
         ^parameter <p>)
   (<ccip> ^left.value > <lr>)
   (<p> ^target-pgm-error-right <lr>)
-->
#   (write (crlf) |Outside error bound right|)
)

sp (attack-delivery*elaborate*state*achieved-delivery*maverick
   (state <s> ^problem-space.name attack-delivery
              ^selected-ordnance <or>
              ^top-state.waypoint.computer.range.round <r>
              ^route <ro>)
   (<or> ^type maverick
         ^min-range > <r>)
-->
   (<ro> ^achieved-delivery *yes*)
)

##############################################################
# propose pilot tasks
#      desired speed
#      deseired heading
#      desired altitude
#
##############################################################
sp (cm*propose*monitor-adjust-speed
   (state <s> ^top-state <ts>
              ^problem-space <ps> )
  -(state <ss> ^superstate <s> ^type state)
   ( <ts>  ^current-time.value <ct>
           ^cog-model.pilot-tasks.speed-time <t3> < <ct>
           ^parameter.zzzstartattacktime <ct2>
   )
   (<ps> ^name wait)
-->
 (<s> ^operator <o> +, = )
 (<o> ^name monitor-adjust-speed )
)
##############################################################
sp (cm*adjust*speed*apply
      (state <s> ^operator <o>
                 ^top-state.current-time.value <ct>
                 ^top-state <ts>
      )
    (<ts> ^cog-model <cm3>
          ^position <ps3>
    )
   (<cm3> ^pilot-tasks <pt3> )
   (<pt3> ^speed-time <t3> < <ct> )
   (<ps3> ^desired-speed <ds3> )
     (<o> ^name monitor-adjust-speed )
-->
 (<pt3> ^speed-time <t3> -
              (+ <ct> 1)
 )
 (<ps3> ^desired-speed <ds3> -
                     247 +
 )
#247.25m/s=480knots
)
##############################################################
sp (cm*adjust*speed*terminate
      (state <s> ^operator <o>
                 ^top-state <ts>
      )
          (<o> ^name monitor-adjust-speed )
-->
(<s> ^operator <o> @ )
)

##############################################################
#sp (cm*propose*monitor-adjust-altitude
#    (state <s> ^top-state <ts>
#               ^problem-space <ps> )
# -(state <ss> ^superstate <s> ^type state)
#    ( <ts>  ^current-time.value <ct>
#            ^cog-model.pilot-tasks.altitude-time <t3> < <ct>
#            ^cog-model.pilot-tasks.speed-time <t4> >= <ct>
#            ^parameter.zzzstartattacktime <ct2>
#    )
#    (<ps> ^name wait)
#-->
#(<s> ^operator <o> +, = )
#(<o> ^name monitor-adjust-altitude )
#)
######
sp (cm*adjust*altitude*apply
      (state <s> ^operator <o>
                 ^top-state.current-time.value <ct>
                 ^top-state <ts>
      )
    (<ts> ^cog-model <cm3>
          ^position <ps3>
    )
   (<cm3> ^pilot-tasks <pt3> )
   (<pt3> ^altitude-time <t3> < <ct> )
   (<ps3> ^desired-altitude <ds3> )
     (<o> ^name monitor-adjust-altitude )
-->
(<pt3> ^altitude-time <t3> -
            (+ <ct> 1)
 )
 (<ps3> ^desired-altitude <ds3> -
                    7500 +
 )
#247.25m/s=480knots
)
##############################################################
sp (cm*adjust*altitude*terminate
      (state <s> ^operator <o>
                 ^top-state <ts>
      )
          (<o> ^name monitor-adjust-altitude )
-->
(<s> ^operator <o> @ )
)
```

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